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EXPERIMENTS

ON

BLEACHING.

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By FRANCIS HOME, M.D.

Fellow of the Royal College of Phyſicians in
Edinburgh.

Των γαρ οντων αγαθων ϗ καλων ȣδεν, ανευ πονȣ ϗ επιμελειας θεοι
διδοασιν ανθρωποις. PROD. DE HERCUL.

To which are Added,

I. An Experimental Eſſay on the Uſe of Leys and Sours in Bleaching. By JAMES FERGUSON, M. D.

II. An Explanation of the Effect of Lime upon Alkaline Salts; and a Method pointed out whereby it may be uſed with Safety and Advantage in Bleaching. By JOSEPH BLACK, M. D.

III. An Abſtract of the foregoing Eſſays, containing, Practical Rules and Plain Directions for the Preparation and Uſe of the Sours made of Oil of Vitriol, and of the Leys made of Bleaching-aſhes with the addition of Quick-lime.

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ADVERTISEMENT.

At the deſire of the Honourable Board of Truſtees for the improvement of fiſheries and manufactures in North Britain, the following treatiſe was compoſed, read in different lectures, and the experiments, ſo far as it was poſſible, were performed before the bleachers of this country. It is now publiſhed in conſequence of a petition preſented by the bleachers to the Honourable Board of Truſtees.

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EXPERIMENTS

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BLEACHING.

PART I.

SECT. I.

Connection of chymiſtry with the arts.

MANUFACTURES are to a country, what aliment is to the human body. They ſupply all waſtes; hinder a nation from preying on itſelf; give it vigour for neceſſary duties; diffuſe the look of health and happineſs over its face; and lay up a ſtore of ſtrength for extraordinary exertions of its power. A wiſe government will no more neglect, or overlook the manufactures of a country, than a wiſe phyſician the diet of one committed to his care.

Let us take a curſory view of the different methods neceſſary to be employed in eſtabliſhing manufactures; for without all, or moſt of thoſe, it is in vain to expect that theſe will ever arrive at any degree of perfection.

We may reduce all the different ways made uſe of to promote manufactures, to two general ſources; the wiſe regulations of the government, and the united efforts of the people where theſe manufactures are eſtabliſhed.

The influence of the government conſiſts in encouraging home manufactures, by granting protection, privileges, immunities and bounties, to ſuch as carry them on; by taking off all duties on the materials uſed in them; by eſtabliſhing proper truſtees to have the inſpection of them, and companies with ſuitable privileges; by ſettling proper funds to be diſtributed in rewards to thoſe who excel; by not making it too burthenſome and expenſive for the manufacturers to obtain good laws; and by a proper regulation of the faſhions at their ſource.

But all theſe advantages are of ſmall avail, if a ready market is not opened; for it is an axiom in trade, that manufactures increaſe only in proportion to the demand for them. Here then will the wiſe politician be again diſcovered, in diſcouraging all foreign manufactures of the ſame kind, by prohibitions, or high duties equivalent to them.

Thanks to the preſent government for their great regard and attention to the manufactures of North Britain. More has been done for it in this way, within theſe few years, than in all thoſe ages which went before. In after times it will be the diſtinguiſhing character of the preſent, That manufactures and induſtry were encouraged in North Britain, nay, introduced into its remoteſt parts. What advantage this will be be to South Britain, is evident to one who conſiders, that the greateſt part of our gains muſt at laſt centre there; and that as much linen was manufactured, even in the confuſion of the year 1745, as in any of the preceding. This fact merits the utmoſt attention; and ſhews, that

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there is not a more proper and effectual antidote againſt rebellion, than induſtry and manufactures.

It is not enough that a government makes wiſe regulations. The leading people of a country muſt lend their united aſſiſtance. From them alone a true ſpirit takes its riſe, and diffuſes itſelf by degrees over the generality of a country. The lower ranks of people are capable of following, though not made for leading. To diſcover the good effects of a general ſpirit in people of rank, let us caſt our eyes on a neighbouring iſland. What well-judged regulations with regard to the whole progreſs of the linen manufacture! what attention and encouragement to every uſeful project! what union and ſpirit in carrying it into execution! what a judicious diſtribution of public and private bounties! what a wiſe inſtitution is their linen-hall in Dublin, in affording a conſtant market for foreign merchants, and a conſtant check to the frauds of private dealers! To their eternal honour be it ſaid, no nation ever made a better uſe of ſo bad a commonalty.

They turn even the vices of their nation to the public benefit. Their foundling-hoſpital, erected for the reception of thoſe children, whom parents either cannot maintain, or do not chuſe to own, is become a ſeminary of induſtry. Of 1500 children, thoſe who are capable from their age, are employed chiefly in ſpinning flax and wool. I had the pleaſure lately to ſee 150 girls, between ſix and twelve years old, ſpinning with both hands. A Scots woman employed to teach them, has a ſalary of 30l. a year ſettled on her by the truſtees. It is no difficult matter to foreſee what great advantage this hoſpital will be to that nation in a few years. Theſe children, when grown up, will ſpread themſelves over the country, teach others, double the quantity of yarn, reduce its price, and put it in their power to underſell others. Such a wiſe regulation in this country, would be the means of ſaving the lives of many innocent children, and many unhappy mothers, and turn to ſome national advantage what we cannot perhaps altogether reſtrain.

I ſhould be guilty of an injuſtice to this country, were I not in a public manner to own the many obligations which we lie under to the Honourable board for the improvement of fiſheries and manufactures in Scotland. Theſe gentlemen, ſince they were firſt conſtituted in the year 1727, have, with unwearied and diſintereſted zeal, contributed in a very great meaſure to raiſe, and direct a ſpirit of induſtry among us, by their own example; by their experience; by adopting the experience of our neighbours; and by diſtributing, with great prudence, thoſe ſmall funds intruſted by the government to their management. For their reward they ſhare the bleſſings of the induſtrious poor.

The great advantage of the linen manufacture, in which point it is allowed to have the preference to the woollen, ariſes from the many changes which that commodity undergoes, before it comes to market; and conſequently its employing many hands. But this advantage makes it more liable to ſuffer from ignorance or fraud; and makes it require more care. There is no part of the manufacture on which its character ſo much depends, as on its management in the bleach-field. On that circumſtance depend its two eſſential qualities, colour and ſtrength. Of ſuch conſequence to the linen trade is that part of its progreſs, that I may ſafely venture to affirm, without aſſuming any title to the ſpirit of prophecy, that the linen manufacture of Ireland, from this cauſe alone, will, nay perhaps has already, come into ſome diſrepute; and muſt at laſt ſuffer, if the Iriſh do not alter their method of bleaching.

We, in this country, have generally followed a better method; but as that ſeems to be owing to our vicinity to Holland, and not to a greater knowledge in the art, we can claim no merit from it. That an art ſo ingenious, ſo difficult, depending ſo much on a nice judgment, conſiſting of ſo many different parts, and withal of ſuch moment to theſe nations, ſhould have lain ſo long neglected, affords matter of ſurpriſe. Thoſe bred to this art are capable of furniſhing materials, but are incapable, as it would ſeem, of reducing it to certain fixed principles. Some knowledge, beſides what the art gives, appears neceſſary even to the art itſelf. This opens another ſource for the improvement of manufactures, viz. the conſideration of thoſe whoſe genius or education has led them to the ſtudy of ſciences and arts, on which theſe manufactures, in a great meaſure, depend. There is no art of ſuch extenſive uſe as chymiſtry.

If chymiſtry was once too wild and extravagant, it has been for many years too tame and confined. It ſeldom ventures further than the compoſition of a medicine, as if that were all the ſervice it could be of to mankind. But chymiſtry is of much greater extent. It claims as its own, all changes that are carried on by fire, or diſſolvents; it looks upon the operators, as entirely under its guidance; the operations to be accounted for only on its principles; and the hopes of further perfection in the art, ſo far as human judgment is concerned, to reſt on it alone. This, and nothing leſs, is true chymiſtry; and may be called Chemia philoſophica, or Philoſophical chymiſtry, as Boyle has termed it; or Univerſal chymiſtry, to uſe Dr. Shaw's expreſſion, in diſtinction to the confined medical chymiſtry.

All arts, excepting thoſe which regard the operations of the mind, may be diſtinguiſhed into mechanical, chymical, or thoſe which partake of both. The mechanical, or ſuch as attain their ends by mechanical inſtruments, are few in reſpect of the chymical, which depend on fire and diſſolvents. In the latter claſs, I rank cookery, tanning, dying, ſmelting, gilding, ſugar-refining, confectionary, baking, brewing, making of ſalt, fermenting of wines and vinegar, the different metallurgic trades, diſtilling, ſoldering, making of ſtarch, glaſs, delf ware, china ware, &c. The mixed arts, which partake ſomewhat of each, are, agriculture, building, printing, making of mirrors, paper, &c.

Let us take a view of the dependence which theſe arts have on chymiſtry. Dying cannot be carried on without it. The inſtruments with which that art works, are, quick-lime, alkaline, and acid ſalts, ſolutions of tin and iron in acids, and neutral ſalts, as alum, ſal ammoniac, and tartarus vitriolatus. Without the aſſiſtance of theſe ſalts, very few colours can be ſtruck on either woollen, linen, or cotton; but with their aſſiſtance all the colouring particles are ſeparated from the water in which they are diſſolved, and fixed on the ſurface of theſe bodies. The durableneſs of colours, and their reſiſtance againſt the effects of ſun and moiſture, are to be explained only from the properties of theſe ſalts. In the ſolutions and mixtures of chymiſtry, many beautiful colours, which were never heard of in the art of dying, ariſe, are changed, or deſtroyed.

The art of tanning is a regular chymical proceſs, not to be underſtood by thoſe who are ignorant of its principles. What account can the tanner give of his firſt operation, ſteeping the hides in lime and water? The chymiſt will inform him, that the intention of it is not only to take off the hair, but to diſſolve the oleaginous particles by the aſſiſtance of lime, that ſo the paſſages may be cleared for the next operation. The former muſt be at as great a loſs to give a reaſon why he ſteeps his hides in water impregnated with oak bark, if the latter did not ſtep into his aſſiſtance, and ſhow him, that the infuſion of bark, by means of its aſtringent ſalt, diſſolved by the water, hardens the animal fibres, and ſhuts up all their pores, ſo that water cannot paſs through them ſo eaſily as it did before. It is he alone who can account for the different effects of the different methods of operating in making ſoft, bend, or ſhamoy leather.

The cook, while he prepares a diſh of ſoup, is in that ſituation a real chymiſt. He operates with the ſame agents the chymiſt operates with, fire, and the diſſolvent or menſtruum water; and with the ſame deſign, to diſſolve ſome part of the meat, and impregnate the water or diſſolvent with theſe particles: but being ignorant of the other branches of chymiſtry, he does not know what parts are diſſolved by the water, how theſe parts are compounded, in what manner they may be ſeparated in greater quantity, or how the whole fibrous parts, nay the bones themſelves, may be diſſolved into a liquor. One who joined this knowledge to his practice, would certainly be a more complete cook than what he was before.

Agriculture, again, is greatly indebted to the powers of mechanics, the plough, harrow, and other inſtruments, for opening and pulveriſing the ground, in order that the plants may be able to puſh their roots to a greater diſtance, that they may take in their food. But what is that food and nouriſhment which is abſorbed by the roots of plants, and without which it is in vain for them to extend their roots? That queſtion I may ſafely venture to affirm is only to be anſwered by a chymiſt. It is he alone who can ſhow the nature and properties of that vegetable food; it is he alone who can tell how it comes there naturally. Experience indeed has learned farmers, that certain ſubſtances fructify the ground: but he, undoubtedly, will be able to produce the greateſt quantity of that food in the ſhorteſt time, who knows what it is, and how produced. So true this is, that though dung is the moſt common compoſt, and has been uſed in all ages; yet I may venture to affirm, that the chymiſt could teach the farmer many uſeful obſervations with reſpect to the management of dunghills. Farming can never be reduced to a regular art, till a farmer ariſe acquainted with chymiſtry.

I know no trade which is ſo entirely the object of chymiſtry as bleaching, and none that has been ſo little conſidered in that light. For what are ſteeping, bucking, ſouring, waſhing with ſoap, alternate wetting and drying, but ſo many proceſſes, that are carried on by theſe powerful chymical agents, heat and diſſolvents? What is the end propoſed, but the diſſolving and carrying off, by the means of acid and alkaline ſalts, moſt powerful menſtruums, ſomewhat which gives the cloth its preſent colour? and what way more certain to carry off whatever is looſened, than the evaporation of water by heat, which is a ſpecies of diſtillation performed in the open air?

I find the moſt ſkilful bleachers underſtand the general theory of their art tolerably well; but being ignorant of the principles of chymiſtry, cannot make the proper uſe of this theory, or apply their knowledge to the advancement of their art. They know that alkaline ſalts diſſolve oils, and that a fermentation is carried on by ſteeping, bucking, and ſouring; but chymiſtry can alone teach them, that by certain methods fermentations may either be quickened, and a great deal of time ſaved; or be checked, and much time loſt; nay, perhaps the effect not produced.

But what the bleachers are moſt deficient in, is a knowledge of the nature and properties of thoſe alkaline ſalts, or aſhes, as they call them, which they make uſe of. Experience has taught them, that theſe ſalts are to be uſed in different proportions; but nothing leſs than a chymical inquiry can diſcover their hidden nature. If this point was once aſcertained, the theory of bleaching would reſt on a more certain foundation than at preſent. For what certain theory can be eſtabliſhed with regard to the operation of thoſe aſhes, when we know not what thoſe aſhes are?

But this is not all the advantage we expect to reap from an examination of this kind. What if theſe bodies are not ſimple alkaline ſalts? For aught we know they may not, but may be a compoſition of different ſubſtances. And what if we diſcover by chymical experiments their compoſition? If this happens to be the caſe, we may perhaps be able to make theſe aſhes at a much cheaper rate in our own country, than what they coſt us when imported from abroad. The inquiry is worthy of the utmoſt attention; and if ſucceſsful, cannot fail to be of great importance to this country. It coſts, as I am told, Great Britain and Ireland 300,000 l. for aſhes every year. It it difficult to ſay to what a ſum that commodity may amount; nay, it is impoſſible to aſſure ourſelves, that we will procure it at any price, when we are told, that the aſhes were monopolized by two Dutch merchants three years ago, and retailed again to us at a double or triple price. Our manufactures could not have ſubſiſted during the late war with Spain, unleſs an order of the King and Council had paſſed, allowing the importation of Spaniſh potaſhes.

aſhes. Both profit and neceſſity contribute to quicken our induſtry.

For the benefit of the linen manufacture of this country, and of our neighbouring iſland, whoſe intereſts appear to be the ſame, and ought always to be united againſt their common competitors in trade, I have applied what little knowledge I have in chymiſtry, and endeavoured to reduce the art of bleaching, hitherto variable and unſafe, to ſome fixed principles, that it might not depend on opinion, or on ſuch experience as always dies with the poſſeſſors.

Were I to make myſelf acquainted with an art of which I was before entirely ignorant, I would naturally inquire into the common practice, or general method of operating in that art; and then endeavour to diſcover the deſign and reaſon of each operation, that I might know, whether the method generally practiſed was the fitteſt to attain the end propoſed. I would certainly endeavour to get a thorough knowledge of the agents or inſtruments made uſe of in the art; what was the beſt way of procuring or making them at home; and what were their effects when applied in the manner that the art directs. I ſhould at laſt conſider the impediments which the art meets with, and the methods of removing them. This is the plan of the following diſquiſition. I have begun with the general methods of bleaching, and deſcribed thoſe moſt approved of. An examination into each particular operation, its effects, the end propoſed, and the beſt methods of accompliſhing it, follows. The nature and compoſition of the different aſhes uſed in bleaching; the method by which theſe ſalts may be made as good at home as thoſe imported from abroad; and their natural effects, when applied to cloth, ſucceed. At laſt is conſidered that great impediment to bleaching, hard water; the method how the greateſt degrees of it may be corrected, is ſhown; and, which is more uſeful to the bleacher, how the ſmalleſt degrees of it may be diſcovered, and ſo ſhunned. I have endeavoured to render the whole as uſeful to our linen trade as poſſible.

There is no way to promote the art of bleaching, which is entirely carried on by the operation of different bodies, but that of experiment: and that alone I have followed. Every other method of advancing the arts is now juſtly derided. It is indeed laborious to the undertaker, and cannot be accompliſhed without accuracy and length of time; it is often unpleaſant to the reader. But, as the former has not deterred me from making the experiments, the latter ſhall not hinder me from narrating them as they were made. No doubt can remain when the experiment is before our eyes. I expect this of others; and, therefore, ſhall follow it myſelf.

An attempt to reduce to a regular ſyſtem, an art, in which nothing has yet appeared in any language, in which we have even no account of the common practice, muſt meet with ſome indulgence as to its faults. Curioſity firſt led me to paſs ſome vacant hours in a bleach-field; and the deſire of making bleaching as certain and regular as other arts, puſhed me on. If the ſyſtem is not entirely complete, I have afforded, I hope, facts and experiments, which will ſerve as a foundation for ſuch a ſuperſtructure. Hippocrates, an author, equally admired for his art and eloquence, had long ago obſerved, ed, “ * That the deſign and labour of ſcience, “ ought to centre in diſcovering what is yet unknown, and may become, when known, uſeful to ſociety; and likewiſe in completing “ what was left by others imperfect.”

SECT. II.

On the different methods of bleaching.

THERE is but one certain way to bring any art or ſcience to perfection; and that is to give an exact detail of every incident which happens in the courſe of practice, and of every change brought about by the application of the agents or inſtruments employed in the art. It is by the hiſtory of diſeaſes and practical caſes, that medicine has arrived to its preſent height. It is from particular ſtatutes and deciſions, that the preſent ſyſtem of law has been compiled. It is from a continuation of this plan, that perfection in theſe ſciences, ſo far as human affairs can attain, is only to be hoped: for on theſe facts alone that theory, which opens a view of the whole art, can be eſtabliſhed.

It is not ſurpriſing, then, that the art of bleaching is ſo imperfect. For what advances could be hoped for in an art, where there was no exact detail of the facts and circumſtances, and where every thing remained a ſecret? It is rather ſurpriſing, that the art has not gone backwards, and been, ere this time, loſt, as has already

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* Εμοι δε το μεν τι των μη ευρημενων εξευρισκειν, ὅ τι ϗ ευρεθεν κρεσσον ἢ ανεξευρετον ξυνεσιος δοκει επιθυμημα τε ϗ εργον ειναι. Δε το τα ημιεργα ες τελος εξεργαρζεσθαι ωσαυτως.

ΙΠΠΟΚΡΑΤΟΥΣ περι τεχνης.

already happened to ſeveral arts for want of a proper hiſtory of them. That ſuch a fate may never happen to this art; that thoſe who are not well acquainted with the practice, may underſtand what follows; that we may have the whole proceſs before our eyes at once, and be able to divide it into its different parts, I ſhall endeavour to trace the great outlines of this art, and ſhow the different methods uſed to bring cloth to its proper degree of whiteneſs.

It was, no doubt, ſoon diſcovered, that the ſun and dews, or frequent watering, were capable, in hot climates, of whitening cloth. This was certainly the moſt antient practice; and is ſtill uſed, as I have been told, in the Eaſt Indies. But colder and more variable climates were obliged to ſubſtitute ſomewhat in the place of the heat which they wanted. Hence the uſe of ſalts in bleaching. Chance no doubt made the firſt diſcovery; but when or where theſe were firſt uſed, hiſtory is ſilent. Their uſe began probably in ſome of our northern countries. The cloth would at firſt be boiled in a lixive of alkaline ſalts, and then expoſed to the influence of the ſun and dews. This method is ſtill uſed in the bleaching of yarn, and coarſe open cloths. But in this climate it is very tedious. I tried the experiment laſt ſummer with ſome coarſe cloth; but after it had been once boiled in a lixive, laid out wet, and expoſed for four months, it had not attained even to a tolerable degree of whiteneſs. The ſummer indeed was unfavourable for the experiment, as there was much rain and little warmth. But from what I ſaw, I ſhould deſpair of ever drawing any advantage from this method.

The two methods of bleaching, eſtabliſhed by a general practice, are, the Dutch, and the Iriſh; one or other is followed at preſent by every bleacher. A deſcription of each of theſe, is then a deſcription of the whole practice. The Dutch method is that moſt followed for fine cloth by the ſkilful bleachers; while, for cheapneſs, they uſe, in the whitening of coarſe cloth, the Iriſh method, or one very like it. I ſhall then give a ſhort deſcription of the facts which happen in each. The Dutch method is as follows.

After the cloth has been ſorted into parcels of an equal fineneſs, as near as can be judged, they are latched, linked, and then ſteeped. Steeping is the firſt operation which the cloth undergoes, and is performed in this manner. The linens are folded up, each piece diſtinct, and laid in a large wooden veſſel; into which is thrown, blood-warm, a ſufficient quantity of water, or equal parts of water and lye, which has been uſed to white cloth only, or water with rye meal or bran mixed with it, till the whole is thoroughly wet, and the liquor riſes over all. Then a cover of wood is laid over the cloth, and that cover is ſecured with a poſt betwixt the boards and the joiſting, to prevent the cloth from riſing during the fermentation which enſues. About ſix hours after the cloth has been ſteeped in warm water, and about twelve in cold, bubbles of air ariſe, a pellicle is formed on the ſurface of the liquor, and the cloth ſwells when it is not preſſed down. This inteſtine motion continues from thirty-ſix to forty-eight hours, according to the warmth of the weather; about which time the pellicle or ſcum begins to fall to the bottom. Before this precipitation happens, the cloth muſt be taken out; and the proper time for taking it out, is when no more air-bubbles ariſe. This is allowed to be the juſteſt guide by the moſt experienced bleachers.

The cloth is then taken out, well rinſed, diſpoſed regularly by the ſelvage, waſhed in the put-mill to carry off the looſe duſt. After this, it is ſpread on the field to dry: when thoroughly dried, it is ready for bucking; which is the ſecond operation.

Bucking, or the application of ſalts, is performed in this manner. The firſt or mother lye is made in a copper, which we ſhall ſuppoſe, for example, when full, holds 170 Scots gallons of water. The copper is filled three fourths full of water, which is brought to boil: juſt when it begins, the following proportion of aſhes is put into it, viz. 30 lb. of blue, and as much white pearl aſhes; 200 lb. of Marcoſt aſhes, (or if they have not theſe, about 300 lb. of Caſhub), 300 lb. of Muſcovy or blanch aſhes; the three laſt ought to be well pounded. This liquor is allowed to boil for a quarter of an hour, ſtirring the aſhes from the bottom very often; after which the fire is taken away. The liquor muſt ſtand till it has ſettled, which takes at leaſt ſix hours, and then it is fit for uſe.

Out of their firſt, or mother lye, the ſecond, or that uſed in bucking, is made in this manner. Into another copper, holding for example 40 Scots gallons, are put 38 gallons of water, 2 lb. ſoft ſoap, and 2 gallons of mother lye; or, for cheapneſs, in place of the ſoap, when they have lye which has been uſed to white linen, called white-linen lye, they take 14 gallons of it, leaving out an equal quantity of water. This is called bucking-lye.

After the linens are taken up from the field dry, they are ſet in the vat or cave, as their large veſſel is called, in rows, end-ways, that they may be equally wet by the lye; which, made blood-warm, is now thrown on them, and the cloth is afterwards ſqueezed down by a man with wooden ſhoes. Each row undergoes the ſame operation, until the veſſel is full, or all the cloth in it. At firſt the lye is put on milk-warm, and after ſtanding a little time on the cloth, it is again let off by a cock into the bucking-copper, heated to a greater degree, and then put on the cloth again. This courſe is repeated for ſix or ſeven hours, and the degree of heat gradually increaſed, till it is at the laſt turn or two thrown on boiling hot. The cloth remains after this for three or four hours in the lye; after which the lye is let off, thrown away, or uſed in the firſt buckings, and the cloth goes on to another operation.

The cloth is then carried out, generally early in the morning, ſpread on the graſs, pinned, corded down, expoſed to the ſun and air, and watered for the firſt ſix hours, ſo often, that it never is allowed to dry. Afterwards it is allowed to lie till dry ſpots appear before it is watered. After ſeven at night it gets no more water, unleſs it be a very drying night. Next day in the morning and forenoon it is watered twice, or thrice if the day is very dry; but if the weather be not drying, it gets no water: after which it is taken up dry if the green is clean; if not, it is rinſed, mill-waſhed, and laid out to dry again, to become fit for bucking.

This alternate courſe of bucking and watering, is performed for the moſt part from ten to ſixteen times, or more, before the linen is fit for ſouring; gradually increaſing the ſtrength of the lye from the firſt to the middle bucking, and from that gradually decreaſing it till the ſouring begins. The lyes in the middle buckings are generally about a third ſtronger than the firſt and laſt.

Souring, or the application of acids to cloth, is the fourth operation. It is difficult to ſay when this operation ſhould commence, and depends moſtly on a length of experience. When the cloth has an equal colour, and is moſtly freed from the ſprat, or outer bark of the lint, it is then thought fit for ſouring; which is performed in the following manner. Into a large vat or veſſel is poured ſuch a quantity of butter-milk, or ſour milk, as will ſufficiently wet the firſt row of cloth; which is tied up in looſe folds, and preſſed down by two or three men bare-footed. If the milk is thick, about an eighth of water is added to it; if thin, no water. Sours made with bran, or rye-meal and water, are often uſed inſtead of milk, and uſed milk-warm. Over the firſt row of cloth a quantity of milk and water is thrown, to be imbibed by the ſecond; and ſo it is continued till the linen to be ſoured is ſufficiently wet, and the liquor riſes over the whole. The cloth is then kept down by covers filled with holes, and ſecured with a poſt fixed to the joiſt, that it may not riſe. Some hours after the cloth has been in the ſour, air-bubbles ariſe, a white ſcum is found on the ſurface, and an inteſtine motion goes on in the liquor. In warm weather it appears ſooner, is ſtronger, and ends ſooner than in cold weather. Juſt before this fermentation, which laſts five or ſix days, is finiſhed, at which time the ſcum falls down, the cloth ſhould be taken out, rinſed, mill-waſhed, and delivered to the women to be waſhed with ſoap and water.

Waſhing with ſoap and water is the fifth operation; and is performed thus. Two women are placed oppoſite at each tub, which is made of very thick ſtaves, ſo that the edges, which ſlope inwards, are about four inches in thickneſs. A ſmall veſſel full of warm water is placed in each tub. The cloth is folded ſo that the ſelvage may be firſt rubbed with ſoap and warm water length-ways, till it is ſufficiently impregnated with it. In this manner all the parcel is rubbed with ſoap, and afterwards carried to be bucked.

The lye now uſed has no ſoap in it, except what it gets from the cloth; and is equal in ſtrength to the ſtrongeſt formerly uſed, or rather ſtronger, becauſe the cloth is now put in wet. From the former operation theſe lyes are gradually made ſtronger, till the cloth ſeems of an uniform white, nor any darkneſs or brown colour appears in its ground. After this the lye is more ſpeedily weakened than it was increaſed; ſo that the laſt which the cloth gets, is weaker than any it got before.

But the management of ſours is different; for they are uſed ſtrongeſt at firſt, and decreaſed ſo in ſtrength, that the laſt ſour, conſidering the cloth is then always taken up wet, may be reckoned to contain three fourths of water.

From the bucking it goes to the watering, as formerly, obſerving only to overlap the ſelvages, and tye it down with cords, that it may not tear; then it returns to the ſour, milling, waſhing, bucking, and watering again. Theſe operations ſucceed one another alternately till the cloth is whitened; at which time it is blued, ſtarched, and dried.

This is the method uſed in the whitening our fine cloths. The following is the method uſed in the whitening of the coarſe.

Having ſorted the cloths according to their quality, they are ſteeped in the ſame manner as the fine, rinſed, waſhed in the mill, and dried before boiling.

In this proceſs, boiling ſupplies the place of bucking, as it takes leſs time, and conſequently is thought cheapeſt. It is done in the following manner: 200lb. Caſhub aſhes, 100 lb. white Muſcovy, and 30 lb. pearl aſhes, boiled in 105 Scots gallons of water for a quarter of an hour, as in the proceſs for the fine cloth, makes the mother or firſt lye. The cloth-boiler is then to be filled two thirds full with water and mother lye, about nine parts of the former to one of the latter; ſo that the lye uſed for boiling the coarſe cloth, is about a third weaker than that uſed in bucking the fine. Such a quantity of cloth is put into the foregoing quantity of lye, when cold, as can be well covered by it. The lye is brought gradually to the boil, and kept boiling for two hours; the cloth being fixed down all the time, that it does not riſe above the liquor.

The

cloth is then taken out, ſpread on the field, and watered, as mentioned before in the fine cloth.

As the ſalts of the lye are not exhauſted by this boiling, the ſame is continued to be uſed all that day, adding, at each boiling, ſo much of the mother lye as will bring it to the ſame ſtrength as at firſt. The lye by boiling loſes in quantity ſomewhat betwixt a third and a fourth; and they reckon that in ſtrength it loſes about a half, becauſe they find in practice, that adding to it half its former ſtrength in freſh lye, has the ſame effect on cloth. Therefore ſome freſh lye, containing a fourth part of the water, and the half of the ſtrength of the firſt lye, makes the ſecond boiler, as they imagine, equal in ſtrength to the firſt. To the third boiler they add ſomewhat more than the former proportion, and go on ſtill increaſing gradually to the fourth and fifth, which is as much as can be done in a day. The boiler is then cleaned, and next day they begin with freſh lye. Theſe additions of freſh lye ought always to be made by the maſter bleacher, as it requires judgment to bring ſucceeding lyes to the ſame ſtrength as the firſt.

When the cloth comes to get the ſecond boiling, the lye ſhould be a little ſtronger, about a thirtieth part, and the deficiencies made up in the ſame proportion. For ſix or ſeven boilings, or fewer, if the cloth be thin, the lye is increaſed in this way, and then gradually diminiſhed till the cloth is fit for ſouring. The whiteſt cloth ought always to be boiled firſt, that it may not be hurt by what goes before.

In this proceſs, if the cloth cannot be got dry for boiling, buſineſs does not ſtop as in the fine;

for after the coarſe has dreeped on racks made for the purpoſe, it is boiled, making the lye ſtrong in proportion to the water in the cloth.

The common method of ſouring coarſe cloth, is, to mix ſome bran and water in the vat; then put a layer of cloth; then more bran, water, and cloth; and ſo on, till the cave is full. The whole is tramped with mens feet, and fixed as in the former proceſs. 1000 yards of cloth, yard broad, require betwixt 4 and 6 pecks of bran. The cloth generally lies about three nights and two days in the ſour. Others prepare their ſour twenty-four hours before, by mixing the bran with warm water in a ſeparate veſſel; and before pouring it on the cloth, they dilute it with a ſufficient quantity of water. After the cloth is taken from the ſour, it ought to be well waſhed and rinſed again. It is then given to men to be well ſoaped on a table, and afterwards rubbed betwixt two rubbing-boards. When it comes from them, it ſhould be well milled, and warm water poured on it all the time, if conveniency will allow of it. Two or three of theſe rubbings are ſufficient, and the cloth very ſeldom requires more.

The lye, after the ſouring begins, is decreaſed in ſtrength by degrees, and three boilings after that are commonly ſufficient to finiſh the cloth. Afterwards it is ſtarched, blued, dried, and bittled in a machine made for that purpoſe, which ſupplies the place of a calendar, and is preferred by many to it.

This method uſed in the bleaching of our coarſe cloths, is very like that practiſed in Ireland both for fine and coarſe. The only material difference is, that there the bleachers uſe no other aſhes but the kelp or Caſhub. A lye is drawn from the former by cold water, which diſſolves the ſalts, and not the ſulphureous particles of the kelp aſhes. This lye is uſed till the cloth is half whitened, and then they lay aſide the kelp lye for one made of Caſhub aſhes. I am told that their moſt ſkilful bleachers have laid aſide the uſe of the kelp aſhes.

Thus I have given a ſhort ſketch of the modern, and moſt approved practice of bleaching; a ſketch ſufficient to conduct thoſe who know a little, though not deſigned to inſtruct thoſe who are entirely ignorant. The practice is, no doubt, capable of great improvements. Some are afterwards attempted; others will be diſcovered by time. It is our buſineſs to forward thoſe diſcoveries, and to open the ſpeedieſt way for attaining and divulging them.

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PART II.

CHAP. I.

Steeping.

IN the preceding hiſtory of bleaching, we may obſerve, that it naturally divides itſelf into ſeveral different branches or parts, all tending to give linen the degree of whiteneſs required. How they effectuate that, comes next under conſideration. If we can ſettle this queſtion, we ſhall be able to diſcover where the preſent practice ſucceeds, and where it fails; we ſhall be able to ſettle principles, by which the art may receive further improvement; we ſhall reduce it to a regular ſcience.

The general proceſs of bleaching divides itſelf into theſe different parts. 1. Steeping and milling. 2. Bucking and boiling. 3. Alternate watering and drying. 4. Souring. 5. Rubbing with ſoap and warm water, ſtarching, and bluing. We ſhall treat of theſe different parts in their order.

Green linen in the different changes which it has undergone before it arrives at that ſtate, contracts a great foulneſs. This is chiefly communicated to it by the dreſſing compoſed of tallow and ſowen, which is a kind of flummery made of bran, flour, or oat-meal ſeeds. The firſt thing to be done in the bleach-field, is to take off all the filth which is foreign to the flax, would blunt the future action of the ſalts, and might, in unſkilful hands be fixed in the cloth. This is the deſign of ſteeping.

To accompliſh this end, the cloth is laid to ſteep, or macerate, as chymiſts call it, in blood-warm water. A ſmaller degree of heat would not diſſolve the dreſſing ſo ſoon; and a greater might coagulate and fix, as will afterwards appear, in the body of the linen, thoſe particles which we deſign to carry off. In a few hours the dreſſing made uſe of in weaving is diſſolved, mixed with the water; and as it had acquired ſome degree of acidity, before application, it becomes a ſpecies of ferment. Each ferment promotes its own particular ſpecies of fermentation, or inteſtine motion; the putrid ferment ſets in motion the putrefactive fermentation; the vinous ferment gives riſe to the vinous fermentation; and the acid ferment to the acetous fermentation. That there is a real fermentation going on in ſteeping, one muſt be ſoon convinced, who attends to the air-bubbles which immediately begin to ariſe, to the ſcum which gathers on the ſurface, and to the inteſtine motion and ſwelling of the whole liquor. That it muſt be the acetous fermentation, appears from this, that the vegetable particles already in part ſoured, muſt firſt undergo this proceſs.

The effect of all fermentations is to ſet the liquor in motion; to raiſe in it a degree of heat; and to emit air-bubbles, which, by carrying up ſome of the light oleaginous particles along with them, produce a ſcum. But as the dreſſing is in ſmall quantity in proportion to the water, theſe effects are gentle and ſlow. The acid ſalts are no ſooner ſeparated by the acetous fermentation, from the abſorbent earth, which made them not perceptible to the tongue in their former ſtate, than they are united to the oily particles of the tallow, which likewiſe adhere ſuperficially, diſſolve them, and render them, in ſome degree, miſſible with water. In this ſtate they are ſoon waſhed off by the inteſtine motion of the liquor. The conſequence of this operation is, that the cloth comes out freed in a great meaſure from its ſuperficial dirt; and more pliant and ſoft than what it was.

Whenever this inteſtine motion is pretty much abated, and before the ſcum ſubſides, bleachers take out their cloth. The ſcum, when no air-bubbles riſe to ſupport it, ſeparates and falls down: and would again communicate to the cloth great part of the filth, when the deſign of this operation was to carry it off. But a longer ſtay would be attended with a much greater diſadvantage. The putrid follows cloſe upon the acetous fermentation: when the latter ends, the former begins. Were this to take place, in any conſiderable degree, it would render the cloth black and tender, as we ſhall have occaſion afterwards to ſhow. Bleachers cannot be too careful in this article.

The firſt queſtion that ariſes to be determined on theſe principles, is, What is the propereſt liquor for ſteeping cloth? Thoſe uſed by bleachers are plain water; white-linen lye and water, equal parts; and rye meal or bran mixed with water. They always make uſe of lye when they have it; a proof that they think it the beſt. They ſay it ferments moſt. Were that really true, I would think the reaſon ſufficient. But there may be a deception in the caſe. That lye is impregnated with much foulneſs, which by riſing to the ſurface may make a thicker ſcum, produce more air-bubbles, and give the appearance of a ſtronger fermentation. The alkaline ſalts, which make part of its compoſition, will attract the acid ſalts generated by the fermentation, and put a ſtop to their junction with the oils. In this view it may do harm. On the other hand, if the alkaline ſalts in it are not compleatly ſaturated, they may be of uſe in uniting with, and carrying off the greaſy particles of the tallow.

Such oppoſite and unſatisfactory views are the common reſult of theory, when we rely entirely upon it for a deciſion. But ſhall we reſt this important queſtion on no better footing than this? Can we find no certain criterion to judge of the propereſt liquor for ſteeping linen? The deſign of the operation will afford us one. The end propoſed by it is to looſen and carry off the ſuperficial foulneſs of the cloth. That liquor then which carries off moſt of it, and makes the cloth lighteſt, muſt be the propereſt. Let us, by this teſt, try theſe different liquors.

Exp. 1. June 25. A web was cut thro' the middle into two pieces; one half of the piece, weighing 4 lb. 1 oz. was ſteeped in milk-warm water; the other half, weighing half an ounce more, was ſteeped in old lye and water, equal parts, and of an equal degree of heat with the former. There was ſome little fermentation in the former, but none in the latter. They were taken out on the 26th, at eleven of the clock in the forenoon, and dried. Each of the pieces now weighed 3 lb. 9½ oz.: ſo that the old lye, by this experiment, appears better for cleaning cloth than plain water, as the former takes out about an eighth part more than the latter.

That I might compare the effects of bran with thoſe of old lye,

Exp. 2. I cut a web into two pieces, and put one part, weighing 5 lb. 1 oz. into bran and warm water; the other, weighing 5 lb. was put into a mixture of old lye and warm water, a third of the former to two thirds of the latter. They lay forty-eight hours in theſe liquors; during which time there was little or no fermentation in the old lye, but a conſiderable degree in the bran and water. When dried, the former piece weighed 4 lb. 13½ oz. the latter 4 lb. 11 oz: That in the bran and water had loſt but 3½ oz. but that in the old lye had loſt 5 oz.

That I might make the ſame trial on greater quantities of cloth,

Exp. 3. I took ſix pieces of cloth, nearly of the ſame fineneſs, and containing twenty-five yards each. Two of theſe weighing 20 lb. 1 oz. were ſteeped in old lye; other two, weighing 18 lb. 15 oz. in bran and water; the remaining two, weighing 19 lb. 13 oz. in plain water. All theſe liquors were of an equal degree of warmth. Theſe lay for forty-eight hours, in the month of June; during which time the fermentation was ſtrongeſt in the bran and water, next in the plain water, and weakeſt in the lye. Taken out and dried, the firſt weighed 18 lb. 12½ oz. and ſo had loſt 1 lb. 4½ oz.; the ſecond weighed 17 lb. 11 oz. and ſo had loſt 1 lb. 4 oz.; the laſt weighed 17 lb. 12. oz. and ſo had loſt 1 lb. 7 oz. The bran and water, in this laſt experiment, appears to have had a better effect than the old lye; and the plain water than either. This queſtion, therefore, ſtill remains undecided. The only method, however, is pointed out, and a multiplicity of experiments muſt be tried, before we can determine what liquor is in general beſt.

After ſteeping, the cloth is carried to the putſtock-mill, to be freed of all its looſe foulneſs. There can be nothing contrived ſo effectual to anſwer the purpoſe as this mill. Its motion is eaſy, regular, and ſafe. While it preſſes gently, it turns the cloth; which is continually waſhed with a ſtream of water. Care muſt be taken that no water be detained in the folds of the linen, otherwiſe that part may be damaged.

SECT. II.

Bucking and boiling.

THIS is the moſt important operation of the whole proceſs, and deſerves a thorough examination. Its deſign is to looſen, and carry off, by the help of alkaline lixives or lyes, that particular ſubſtance in cloth, which is the cauſe of its brown colour. The ſalts, or aſhes, as the bleachers call them, uſed in the compoſition of the lye, demand, for many reaſons, a particular ſcrutiny; and therefore I ſhall examine them afterwards by themſelves.

Theſe aſhes, the pearl excepted, ought to be well pounded, before they are put into the copper; for the Marcoft and Caſhub are very hard, and with ſome difficulty yield their ſalts.

As theſe two laſt contain a very conſiderable proportion of a real ſulphureous matter, which muſt in ſome degree tinge white cloth; and as this is diſſolved much more by boiling, than by the inferior degrees of heat, while the ſalts may be as well extracted by the latter, I would propoſe that the water ſhould never be brought to boil, and ſhould be continued for ſome time longer under that degree of heat. The pearl aſhes ſhould never be put in till near the end, as they are eaſily diſſolved in water.

If the ſalts were always of an equal ſtrength, the ſame quantities would make a lye equally ſtrong: but they are not. Salts of the ſame name differ very much from one another. The Muſcovy aſhes are turning weaker every day, as every bleacher muſt have obſerved, till at laſt they turn quite effete. A decoction from them, when new, muſt differ very much from one when they have been long kept. Hence a neceſſity of ſome exact criterion to diſcover when lyes are of an equal ſtrength. The taſte cannot ſerve, as that is ſo variable, cannot be deſcribed to another, and is blunted by repeated trials. The proof-ball will ſerve the purpoſe of the bleach-field ſufficiently; and by diſcovering the ſpecific gravity, will ſhow the quantity of alkaline ſalts diſſolved. But it cannot ſhow the dangerous qualities of theſe ſalts; for the leſs cauſtic and leſs heavy this liquor is, the more dangerous and corroſive it may be for the cloth.

This muſt appear a paradox at preſent, but will afterwards be proved by many experiments. The third lye, which they draw from theſe materials by an infuſion of cold water, where I could plainly taſte the lime, appears to me more dangerous than the firſt. The ſecond lye, which they extract from the ſame aſhes, and which is reckoned about a third in ſtrength, when compared to the firſt, muſt be of the ſame nature; nor do I think it ſhould be uſed without an addition of pearl aſhes, which will correct it.

It is taken for a general rule, That the ſolution of any body in its menſtruum is equally diffuſed through the whole liquor. The bleachers depending on this, uſe equal quantities of the top and bottom of their lye, when once clear and ſettled; taking it for granted, that there is an equal quantity of ſalts in equal quantities of the lye. But if there is not, the miſtake may be of fatal conſequence; as the lye may be in ſome places ſtronger than what the cloth can with ſafety bear. That general law of ſolution muſt have taken its riſe from particular experiments, and not from reaſoning. Whether a ſufficient number of experiments have been tried to aſcertain this point, and to eſtabliſh an undoubted general rule, may be called in queſtion.

But when I had diſcovered that lime makes part of the diſſolved ſubſtance, and reflected how long its groſſer parts will continue ſuſpended in water, there appeared ſtronger reaſons for my ſuſpecting that this rule, though it may be pretty general, does not take place here; at leaſt it is worth the purſuit of experiment.

Exp. 4. I weighed at the bleachfield a piece of glaſs in ſome cold lye, after it had been boiled, ſtood for two days, and about the fourth part of it had been uſed. The glaſs weighed 3 drachms 1½ grains in the lye, and 3 drachms 7½ grains in river-water. The ſame glaſs weighed in the ſame lye, when almoſt all uſed, 2 grains leſs than it had done before. This ſhows, that the laſt of the lye contained a third more of the diſſolved body; and, conſequently, was a third ſtronger than the firſt of the lye.

As this might, perhaps, be owing to a continuation of the ſolution of the ſalts, I repeated the experiment in a different way.

Exp. 5. I took from the ſurface ſome of the lye, after the ſalts were diſſolved, and the liquor was become clear. At the ſame time I immerſed a bottle, fixed to a long ſtick, ſo near the bottom, as not to raiſe the aſhes there, and, by pulling out the cork by a ſtring, filled the bottle full of the lye near the bottom. The glaſs weighed in river-water 3 drachms 38½ grains; in the lye taken from the ſurface 3 drachms 34½ grains; and in the lye taken from the bottom 3 drachms 31½ grains. This experiment ſhows, that the lye at the bottom was, in this caſe, ¼ ſtronger than the lye at the ſurface.

At other times when I tried the ſame experiment, I found no difference in the ſpecific gravity; and, therefore, I leave it as a queſtion yet doubtful, though deſerving to be aſcertained by thoſe who have an opportunity of doing it. As the lye ſtands continually on the aſhes, there can be no doubt but what is uſed laſt muſt be ſtronger than the firſt. I would, therefore, recommend, to general practice, the method uſed by Mr. John Chriſtie, who draws off the lye, after it has ſettled, into a ſecond receptacle, and leaves the aſhes behind. By this means it never can turn ſtronger; and he has it in his power to mix the top and bottom, which cannot be done ſo long as it ſtands on the aſhes.

Having conſidered the lye, let us next inquire how it acts. On this inquiry depends almoſt the whole theory of bleaching, as its action on cloth is, at leaſt in this country, abſolutely neceſſary. We ſhall ſee, in ſome experiments which follow on the natural effects of theſe aſhes, that one effect they have on cloth, is the diminiſhing of its weight; and that their whitening power is, generally, in proportion to their weakening power. Hence ariſes a probability, that theſe lyes act by removing ſomewhat from the cloth, and that the loſs of this ſubſtance is the cauſe of whiteneſs. This appears yet plainer, when the bucking, which laſts from Saturday night to Monday morning, is attended to. There I have ſeen evident ſigns of a ſolution going on from the quantity of air-bubbles ariſing, when the liquor was almoſt cold.

There are various and different opinions with regard to the operation of theſe ſalts: That they act by altering the external texture of the cloth, or by ſeparating the mucilaginous parts from the reſt, or by extracting the oil which is laid up in the cells of the plant. The laſt is the general opinion, or rather conjecture, for none of them deſerves any better name; but we may venture to affirm, that it is ſo without any better title to pre-eminence, than what the others have. Alkaline ſalts diſſolve oils, therefore theſe ſalts diſſolve the cellular oil of the cloth, is all the foundation which this theory has to reſt on; too ſlight, when unſupported by experiment, to be relied on.

In ſettling this queſtion, we ſhall not only fix the theory of bleaching, but likewiſe that of the lithontriptic quality of medicines, whoſe effects on the human calculus are obſerved to be the ſame as the effects of theſe materials on cloth. The ſolvents of the ſtone, and the bleaching materials, are the ſame. They produce ſimilar effects on both; ſuch as diminution of weight, a white colour, the generation of much elaſtic air, and at laſt a diſſolution or ſeparation of parts. But their method of acting has not yet been aſcertained by any certain and concluſive experiment. Let us then bring the queſtion, if we can, to that teſt.

Wax is whitened by being expoſed to the influence of the ſun, air, and moiſture. A diſcovery of the changes made on it by bleaching, may throw a light upon the queſtion.

Exp. 6. Six drachms of wax were ſliced down, expoſed on a ſouth window, September 10. and watered. That day being clear and warm, bleached the wax more than the following. It ſeemed to me to whiten quicker when it had no water thrown on it than when it had. Sept. 15. it was very white, and 1 drachm 3 grains lighter. 3 ½ drachms of this bleached wax, and as much of unbleached, taken from the ſame piece, were made into two candles of the ſame length and thickneſs, having cotton wicks of the ſame kind. The bleached candle burned one hour thirty-three minutes; the unbleached three minutes longer. The former run down four times, the latter never. The former had an obſcure light and dull flame; the latter had a clear pleaſant one, of a blue colour at the bottom. The former when burning ſeemed to have its wick thicker, and its flame nearer the wax, than the latter. The former was brittle, the latter not. It plainly appears from theſe facts, that the unbleached wax was more inflammable than the bleached; and that the latter had loſt ſo much of an inflammable ſubſtance, as it had loſt in weight; and conſequently the ſubſtance loſt in bleaching of wax is the oily part. Dr. Hales obſerves, that wax in diſtillation affords an inflammable vapour.

As I had not an opportunity of repeating the former experiment, I do not look on it as entirely concluſive; for it is poſſible that ſome of the duſt, flying about in the air, might have mixed with the bleached wax, and ſo have rendered it leſs inflammable. Nor do I think the analogical reaſoning from wax to linen without objections. Let us try then if we cannot procure the ſubſtance extracted from the cloth, ſhow it to the eye, and examine its different properties. The proper place to find it, is in a lye already uſed, and fully impregnated with theſe colouring particles.

Exp. 7. I got in the bleach-field ſome lye, which had been uſed all that day for boiling coarſe linen, which was tolerably white, and had been twice boiled before. There could be no dreſſing remaining in theſe webs. No ſoap had ever touched that parcel; nor do they mix ſoap with the lye uſed for coarſe cloth. Some of this impregnated lye was evaporated, and left a dark-coloured matter behind. This ſubſtance felt oily betwixt the fingers, but would not lather in water as ſoap does. It deflagrated with nitre in fuſion, and afforded a tincture to ſpirit of wine. By this experiment the ſalts ſeem to have an oily inflammable ſubſtance joined with them.

Could we ſeparate this colouring ſubſtance from theſe ſalts, and exhibit it by itſelf, ſo that it might become the object of experiment, the queſtion would be ſoon decided. Here chymiſtry lends us its aſſiſtance. Whatever has a ſtronger affinity or attraction to the ſalts with which it is joined, than this ſubſtance has, muſt ſet it at liberty, and make it viſible. Acids attract alkaline ſalt from all other bodies; and therefore will ſerve our purpoſe.

Exp. 8. Into a quantity of the impregnated lye mentioned in the former experiment, I poured in oil of vitriol. Some bubbles of air aroſe, an inteſtine motion was to be perceived, and the liquor changed its colour from a dark to a turbid white. It curdled like a ſolution of ſoap, and a ſcum ſoon gathered on the ſurface, about half an inch in thickneſs, the deepneſs of the liquor not being above ſix inches. What was below was now pretty clear. A great deal of the ſame matter lay in the bottom; and I obſerved, that the ſubſtance on the ſurface was precipitated, and ſhowed itſelf heavier than water, when the particles of air, attached to it in great plenty, were diſpelled by heat. This ſubſtance was in colour darker than the cloth which had been boiled in it.

I procured a conſiderable quantity of it by ſkimming it off. When I tried to mix it with water, it always fell to the bottom. When dried ed by the air, it diminiſhed very much in its ſize, and turned as black as a coal. In this ſtate it deflagrated ſtrongly with nitre in fuſion; gave a ſtrong tincture to ſpirit of wine; and when put on a red-hot iron, burnt very ſlowly, as if it contained a heavy ponderous oil; and left ſome earth behind.

From the inflammability of this ſubſtance, its rejecting of water, and diſſolving in ſpirit of wine, we diſcover its oleaginous nature; but from its great ſpecific gravity we ſee, that it differs very much from the expreſſed or cellular oil of vegetables; and yet more from their mucilage. That it diſſolves in ſpirit of wine, is not a certain argument of its differing from expreſſed oils; becauſe theſe, when joined to alkaline ſalts, and recovered again by acids, become ſoluble in ſpirit of wine. The quantity of earthy powder left behind after burning, ſhews that it contains many of the ſolid particles of the flax. The ſubſtance extracted from cloth by alkaline lyes appears then to be a compoſition of a heavy oil, and the ſolid earthy particles of the flax. Whether this heavy oil differs originally in the plant, from the oil expreſſed in its cells, or whether the latter is converted into the former, by loſing in ſolution great part of its air, I cannot determine; nor is it neceſſary. At preſent they ſeem widely different.

In what manner theſe ſalts act ſo as to diſſolve the oils, and detach the ſolid particles, whether from a certain polarity, as Dr. Hales imagines, or from other cauſes, of which the imagination can ſuggeſt many, is not allowed us certainly to know. The ſpeculation is too ſubtile to admit of experiments, aud too uncertain to be truſted to without theſe. It is enough for us to know on what principles in the cloth theſe ſalts operate. We ſee evidently how much cloth muſt be weakened by an improper uſe of theſe ſalts, as we find the ſolid particles themſelves are ſeparated.

It is neceſſary that cloth ſhould be dry before bucking, that the ſalts may enter into the body of the cloth along with the water; for they will not enter in ſuch quantity, if it be wet; and by acting too powerfully on the external threads, may endanger them.

The degree of heat is a very material circumſtance in this operation. As the action of the ſalts is always in proportion to the heat, it would appear more proper to begin with a boiling heat, by which a great deal of time and labour might be ſaved. The reaſon why this method is not followed, appears to be this. If any vegetable or vegetable ſubſtance is to be ſoftened, and to have its juices extracted, it is found more proper to give it gentle degrees of heat at firſt, and to advance gradually, then to plunge it all at once in boiling water. This laſt degree of heat is ſo ſtrong, that when applied at once to a vegetable, it hardens, inſtead of ſoftening its texture. Dried vegetables are immediately put into boiling water by cooks, that theſe ſubſtances may preſerve their green colour, which is only to be done by hindering them from turning too ſoft. Boiling water has the ſame effect on animal ſubſtances; for if ſalt beef is put into it, the water is kept from getting at the ſalts, from the outſide of the beef being hardened.

But when we conſider, how much of an oily ſubſtance there is on the cloth, eſpecially at firſt, which will for ſome time keep off the water, and how the twiſting of the threads, and cloſeneſs of the texture, hinders the water from penetrating, we ſhall find, that if boiling water were put in at once, the cloth might be liable, in ſeveral parts, to a dry heat, which would be much worſe than a wet one. That the lyes have not acceſs to all parts of the cloth, at firſt, appears plainly from this, That when it has lain, after the firſt bucking, till the lyes are waſhed out, it is as black, in ſome parts, as when it was ſteeped. This muſt be owing to the diſcharge of the colouring particles from thoſe places to which the lye has acceſs, and to their remaining where it has not. It would ſeem adviſeable, then, in the firſt bucking or two, when the cloth is foul, to uſe the lye conſiderably below the boiling point; that by this ſoaking, or maceration, the foulneſs may be entirely diſcharged, and the cloth quite opened for the ſpeedy reception of the boiling lye in the buckings which follow.

The lyes ſhould likewiſe be weakeſt in the firſt buckings, becauſe then they act only on the more external parts; whereas, when the cloth is more opened, and the field of action is increaſed, the active powers ought to be ſo too. For this reaſon they are at the ſtrongeſt after ſome ſourings.

I was of opinion, that the cloth was allowed to lie too ſhort time in the lye, and that more time was conſumed in the bleaching of cloth than was neceſſary. What confirmed my ſuſpicions was, that I obſerved the cloth which lay in the bucking-vat from Saturday night to Monday morning, come out of a deeper colour, and when expoſed to the air, became whiter, than the others of the ſame parcel, which had been in the lye for twelve hours only. I cauſed the experiment to be tried on a whole parcel every time they were bucked; and they advanced faſter, and with as great ſafety, as other pieces which were managed in the common way. As to the effect of ſoap mixed with the lye, I ſhall have occaſion afterwards to ſhow, that it has no power in correcting the dangerous qualities of the lye. At the ſame time we ſhall diſcover, what is the proper corrector.

The only thing that now remains to be conſidered, is, the management of the coarſe cloth, where boiling is ſubſtituted inſtead of bucking. This ſpecies of linen cannot afford the time and labour neceſſary for the latter operation; and therefore they muſt undergo a ſhorter, and more active method. As the heat continues longer at the degree of boiling, the lyes uſed to the coarſe cloth muſt be weaker than thoſe uſed to the fine. There is not ſo much danger from heat in the coarſe, as in the fine cloth, becauſe the former is of a more open texture, and will allow the lye to penetrate more ſpeedily. In the cloſer kinds, however, I would adviſe, that the firſt application of the ſalts ſhould be made without a boiling heat.

I cannot help greatly condemning the method generally uſed, of boiling all the cloth of that day in the ſame lye. I can ſee no certainty of having all the lyes of the ſame ſtrength, becauſe neither the taſte nor proof-ball can be of uſe here; the taſte, becauſe the oily matter ſheathes the ſalts; the proof-ball, becauſe there is another ſubſtance here beſides ſalts. But I am ſure of this, that ſo much filth, as a former experiment ſhowed in lye often uſed, cannot but communicate ſome of itſelf to the cloth, and inſtead of advancing, retard its whiteneſs. It will appear afterwards, from experiments, that cloth boiled in a foul lye becomes heavier, and conſequently takes in part of its foulneſs. If it is done for cheapneſs, I am not of opinion, that it will turn out ſo on a further examination; for the laſt additions of freſh lye muſt be blunted greatly by the foulneſs of the old lye; and the bleachers themſelves obſerve, that they have not ſuch a ſtrong effect as the firſt. No lye, therefore, can with any advantage be uſed above twice.

SECT. III.

Alternate watering and drying.

AFTER the cloth has been bucked, it is carried out to the field, and frequently watered for the firſt ſix hours. For if, during that time, when it is ſtrongly impregnated with ſalts, it is allowed to dry, the ſalts approaching cloſer together, and, aſſiſted by a greater degree of heat, increaſing always in proportion to the drineſs of the cloth, act with greater force, and deſtroy its very texture. After this time, dry ſpots are allowed to appear before it gets any water. In this ſtate I imagine it profits moſt, as the latter part of the evaporation comes from the more internal parts of the cloth, and will carry away moſt from thoſe parts. The bleaching of the wax, in a preceding experiment, helps to convince me of this; for it ſeemed to whiten moſt when the laſt particles of water were going off.

This continued evaporation from the ſurface of the cloth ſhows, that the deſign of the operation is to carry off ſomewhat remaining after the former proceſs of bucking. This appears likewiſe from a fact known to all bleachers, that the upper ſide of the cloth, where the evaporation is ſtrongeſt, attains to a greater degree of whiteneſs than the under ſide. But it is placed beyond all doubt by the experiment in ſect 1. of part 4.; where it appears, that cloth turns much lighter by being expoſed to the influence of the ſun, air, and winds, even though the ſalts have been waſhed out of it.

What, then, is this ſubſtance? As we have diſcovered in the former ſection, that the whitening, in the operation of bucking, depends on the extracting or looſening the heavy oil, and ſolid particles of the flax; it appears highly probable, that the effects of watering, and expoſition to the ſun, air, and winds, are produced by the evaporation of the ſame ſubſtance, joined to the ſalts, with which compoſite body the cloth is impregnated when expoſed on the field. That theſe ſalts are in a great meaſure carried off or deſtroyed, appears from the cloth's being allowed to dry without any danger, after the evaporation has gone on for ſome time. If we can ſhow, that oils and ſalts, when joined together, are capable of being exhaled, in this manner, by the heat of the atmoſphere, we ſhall reduce this queſtion to a very great degree of certainty.

Exp. 9. Sept. 10. I expoſed, in a ſouth-weſt window, half an oz. of Caſtile ſoap, ſliced down, and watered. Sept. 14. when well dried, it weighed but 3 dr. 6 gr. Sept. 22. it weighed 2 dr. 2 gr. Sept. 24. it weighed 1 dr. 50 gr. It then ſeemed a very little whiter; but was much more mucilaginous in its taſte, and had no degree of ſaltneſs, which it had before.

It appears, from this experiment, that ſoap is ſo volatile, when watered, and expoſed to air not very warm, that it loſes above half its weight in fourteen days. The ſame muſt happen to the ſaponaceous ſubſtance, formed from the conjunction of the alkaline ſalts, heavy oil, and earthy particles of the flax. The whole deſign, then, of this operation, which, by way of pre-eminence, gets the name of bleaching, is to carry off, by the evaporation of water, whatever has been looſened by the former proceſs of bucking.

Againſt this doctrine there may be brought two objections, ſeemingly of great weight. It is a general opinion amongſt bleachers, that linen whitens quicker in March and April, than in any other months: but as the evaporation cannot be ſo great at that time, as when the ſun has a greater heat; hence the whitening of cloth is not in proportion to the degree of evaporation; and therefore the former cannot be owing to the latter. This objection vaniſhes, when we conſider, that the cloth comes firſt into the bleachfield, in the ſpring, is cloſely attended, having no other to interfere with it, for ſome time; and, as it is the whiteſt, gets, in the after buckings, the firſt of the lye; while the ſecond parcel is often bucked with what has been uſed to the firſt. Were the fact true, on which the objection is founded, this would be a ſufficient anſwer to the objection. But it appears not to be true, from an obſervation of Mr. John Chryſtie, That cloth laid down in the beginning of June, and finiſhed in September, takes generally leſs work, and undergoes fewer operations, than what is laid down in March, and finiſhed in June.

The other objection is, That cloth dries much faſter in windy weather than in calm ſunſhine; but it does not bleach ſo faſt. This would ſeem to ſhow, that the ſun has ſome particular influence independent on evaporation. In anſwer to this objection, let it be conſidered, that it is not the evaporation from the ſurface, but from the more internal parts, as I ſaid before, that is of benefit to the cloth. Now, this latter evaporation muſt be much ſtronger in ſunſhine than in windy weather, on account of the heat of the ſun, which will make the cloth more open; while the coldneſs of windy weather muſt ſhut it up, ſo that the evaporation will all be from the ſurface. Clear ſunſhine, with a very little wind, is obſerved to be the beſt weather for bleaching; a convincing proof that this reaſoning is juſt.

It would ſeem to follow, as a corollary from this reaſoning, that the number of waterings ſhould, in general, be in proportion to the ſtrength of the lye; for the ſtronger the lye is, the more there is to be evaporated; and the greater the danger, in caſe the cloth ſhould be allowed to dry. But there is an exception to this general rule, ariſing from the conſideration of another circumſtance. It is obſerved, that cloth, when brown, dries ſooner, than when it becomes whiter, ariſing from the cloſeneſs and oilineſs, which it then has, not allowing the water a free paſſage. Perhaps that colour may retain a greater degree of heat, and in that way aſſiſt a very little. Cloth, therefore, after the firſt buckings, muſt be more carefully watered than after the laſt.

It follows likewiſe from this reaſoning, that the ſoil of the bleach-field ſhould be gravelly or ſandy, that the water may paſs quickly through it, and the heat may be increaſed by the reflection of the ſoil: for the ſucceſs of this operation depends on the mutual action of heat and evaporation. It is likewiſe neceſſary that the water ſhould be light, ſoft, and free from mud or dirt, which, not being able to riſe along with the water, muſt remain behind. When there is much of this, it becomes neceſſary to rinſe the cloth in water, and then give it a milling, to take out the dirt; elſe it would be fixed in the cloth by the following bucking, as it is not ſoluble by the lye.

This operation has more attributed to it by bleachers than it can juſtly claim. The cloth appears, even to the eye, to whiten under theſe alternate waterings and dryings; and theſe, naturally, get the honour of it, when it more properly belongs to the former operations. Here lies the fallacy. Alkaline ſalts give a very high colour to the decoctions, or infuſions of vegetables. This is probably owing to the ſolution of the oleaginous colouring particles of the plant; which particles, being opened and ſeparated by the ſalts, occupy a greater ſpace, and give a deep colour to the liquor. The cloth participates of the liquor and colour. Hence bleachers always judge of the goodneſs of the bucking by the deepneſs of its colour. The rule, in general, is good. I obſerve, that in thoſe buckings which continue from the Saturday night to the Monday morning, the cloth has always the deepeſt colour. When that cloth has been expoſed ſome hours to the influence of the air, theſe colouring particles, which are but looſely attached to it, are evaporated, and the linen appears of a brighter colour. This operation does no more than complete what the former had almoſt finiſhed. If its own merit were thoroughly known, there would be no occaſion to attribute that of another operation to it. Thread, and open cloths, ſuch as diaper, may be reduced to a great degree of whiteneſs, after one bucking, by it alone. No cloth, as would appear, can attain to a bright whiteneſs without it.

Since the only advantage of watering is the removal of the ſalts, and what they have diſſolved, might we not effectuate this by ſome cheaper, and more certain method? For it occupies many hands; and muſt depend, altogether, on the uncertainty of the weather; ſo that, in the beginning of the ſeaſon, the bleacher is often obliged to repeat his buckings without bleaching. We might take out the alkaline ſalts by acids; but then the other ſubſtance would be left alone in the cloth, nor would any waſhing be able to remove it. Mill-waſhing appears a more probable method of taking out both ſalts and oils; and it would ſeem that this might, in a great meaſure, ſupply the place of watering; but upon trial it does not ſucceed. Two parcels of linen were managed equally in every other reſpect, except in this, That one was watered, and expoſed to the influence of the air, and the other was only mill-waſhed. This method was followed until they were fit for ſouring. The cloth which had been mill-waſhed, had a remarkable green colour, and did not recover the bright colour of the pieces managed in the common way, until it had been treated like them for a fortnight. The green colour was certainly owing to a precipitation of the ſulphureous particles, with which the lye is impregnated, upon the ſurface of the cloth; owing to the ſalts being waſhed off more ſpeedily than the ſulphur, to which they are united in the lye. The attachment betwixt theſe two bodies, we know, is very looſe, and the ſeparation eaſily made. Evaporation, then, alone is ſufficient to carry off theſe ſulphureous particles.

SECT. IV.

Souring.

IT is well known to all chymiſts, and will afterwards appear, that alkaline ſalts are convertible, by different methods, into abſorbent earths. Frequent ſolution in water, and evaporation of it again, is one of theſe. This tranſmutation, then, of theſe ſalts, which are not volatiliſed, or waſhed away, muſt be continually going on in the cloth under theſe alternate waterings and dryings of the former proceſs. Not much, indeed, after the firſt two or three buckings; becauſe the ſalts, not having entered deep into the cloth, are eaſily waſhed off, or evaporated. But when they penetrate into the very compoſition of the laſt and minuteſt fibres, of which the firſt veſſels are made, they find greater difficulty of eſcaping again, and muſt be more ſubject to this tranſmutation. But if we conſider the bleaching aſhes as a compoſition of lime and alkaline ſalts, we muſt diſcover a freſh fund for the depoſition of the abſorbent earth. The common cauſtic, a compoſition of this very kind, ſoon converts itſelf, if expoſed to the open air, into a harmleſs earthy powder.

Frequent buckings and bleachings load the cloth with this ſubſtance. It becomes, then, neceſſary to take it out. No waſhing can do that, becauſe earth is not ſoluble in water. Nothing but acids can remove it. Theſe are attracted by the abſorbent earth, join themſelves to it, and compoſe a kind of neutral imperfect ſalt, which is ſoluble in water; and therefore eaſily waſhed out of the cloth. The acid liquors commonly uſed are butter milk, which is reckoned the beſt; ſour milk; infuſions of bran, rye-meal, &c. kept for ſome days till they ſour. Sour whey is thought to give the cloth a yellow colour.

The linen ought to be dried before it is put in the ſour, that the acid particles may penetrate, along with the watery, thro' the whole. A few hours after it has been there, air-bubbles ariſe, the liquor ſwells, and a thick ſcum is formed; manifeſt ſigns of a fermentation. The following experiment ſhows the degree of heat which attends it.

Exp. 10. May 25. I put a thermometer of Fahrenheit's into ſome butter milk of which the bleachers were compoſing their ſours, and which ſtood in a vat adjoining to another, where the milk was the ſame, and the ſouring proceſs had been going on for two days. After the thermometer had been twenty minutes in the butter milk, the mercury ſtood at 64 degrees. In the ſouring vat it roſe to 68 degrees. An increaſe of 4 degrees ſhows a pretty briſk inteſtine motion.

To what are all theſe effects owing? To the acetous fermentation going on in thoſe vegetable liquors, whoſe acids, extricating themſelves, produce heat, inteſtine motion, and air-bubbles. As the change is ſlow, the proceſs takes five or ſix days before it is finiſhed. During this time the acid particles are continually uniting themſelves to the abſorbent earth in the cloth. That this fermentation goes on in the liquor alone, appears from this conſideration, that the ſame effects, viz. air bubbles, and ſcum, are to be ſeen in the butter milk alone. The only effect, then, it has, ſo far as I can ſee, is, by the ſmall degree of heat, and inteſtine motion, which attend it, to aſſiſt the junction of the acid and abſorbent particles. We ſhall preſently ſee, that this proceſs may be carried on, to as great advantage, without any fermentation; and therefore it appears not abſolutely neceſſary.

When thoſe abſorbent particles are fully ſaturated, the remaining acids may unite with, and have ſome ſmall effect in extracting the colouring particles. This appears from the two following experiments.

Exp. 11. Sept. 20. A piece of cloth which had been ſteeped, weighing 41 ½ gr. was put into a half-pound of butter milk, whigged, and well ſoured, by a mixture of water, and by boiling. Sept. 24. when taken out, and waſhed in water, it appeared a very little whiter. The mineral acids, as will appear afterwards, whiten cloth, even though they are very much diluted.

Juſt before the acetous fermentation is finiſhed, the cloth ſhould be taken out; otherwiſe the ſcum will fall down, and lodge in the cloth, and the putrefaction, which then begins, will weaken it. This appears from the following experiment.

Exp. 12. Sept. 16. A piece of cloth weighing 42 gr. was laid in butter milk unwhigged. Nov. 15. the milk had a putrified ſmell. The cloth was a little whiter, but very tender; and weighed, when well waſhed in warm water, and dried, 40 gr.

All the ſours made of bran, rye-meal, &c. ought to be prepared before uſe; for by this means ſo much time will be ſaved. Beſides, when the water is poured upon the cloth, and bran, as is done in the management of coarſe cloth, the linen is not in a better ſituation than if it had been taken up wet from the field; and by this means the acid particles cannot penetrate ſo deep. Again, this method of mixing the bran with the cloth, may be attended with yet worſe conſequences. All vegetable ſubſtances, when much preſſed, fall into the putreſcent, and not the acetous fermentation. This muſt, and does happen to the bran preſſed betwixt the different layers of the linen. I had occaſion to ſee it one day, in a bleachfield, when they were drawing a parcel of coarſe cloth ſoured in this manner. The bran had attained to a conſiderable degree of putrefaction, but the liquor had not. The cloth, immediately above and below the putrid bran, muſt have been weakened by it. For theſe obvious reaſons I would propoſe, that all the ſours ſhould be prepared before the cloth is ſteeped in them; and that none of the bran, or meal, ſhould be mixed with the cloth.

The ſours are uſed ſtrongeſt at firſt, and gradually weakened till the cloth has attained to its whiteneſs. In the firſt ſourings, there is more of the earthy matter in the cloth, from the many buckings it has undergone, than what there can be afterwards. As the quantity of this matter decreaſes, ſo ſhould the ſtrength of the ſour. I am not, however, of opinion, that there is the leaſt danger at any time, from too ſtrong a ſour. Why they ſhould not be uſed ſomewhat ſooner than they are, I could never ſee any reaſon.

What is moſt wanted in this operation, is, a more expeditious and cheaper method of obtaining the ſame end. As it takes five or ſix days, it retards the whitening of the cloth conſiderably; and as bleachers are obliged to ſend for milk to a great diſtance, it becomes very dear. This laſt conſideration makes them keep it ſo long, that, when uſed, it can have no good effect; perhaps it may have a bad.

There is one conſideration that may lead us to ſhorten the time. It is obſerved, that the ſouring proceſs is ſooner finiſhed in warm than in cold weather. Heat quickens the fermentation, by aiding the inteſtine motion. I would purpoſe, then, that the vats ſhould not be buried in the ground, as they always are, which muſt keep them cold; and that there ſhould be pipes along the walls of the room, to give it that degree of heat, which, on trial, may be found to anſwer beſt. I am of opinion, that there are few days in ſummer ſo hot as is neceſſary; and that the beginning and end of the ſeaſon, is by very much too cold. That this is no ideal ſcheme, the following fact is a ſufficient proof. There are two vats in Salton bleachfield, adjoining to a partition wall, at the back of which there is a kitchen-fire. In theſe vats the ſouring proceſs is finiſhed in three days, whereas it laſts five or ſix days in the others placed round the ſame room.

This improvement, though it ſhortens the time of ſouring a very little, yet is no remedy againſt the ſcarcity and dearneſs of milk ſours. Such a liquor as would ſerve our purpoſe, muſt be found either among the vegetable acids, which have no further fermentation to undergo, or among the mineral acids. The former are a large claſs, and contain within themſelves many different ſpecies, ſuch as the acid juice of ſeveral plants, vinegars made of fermented liquors, and acid ſalts called tartars. But there is one objection againſt all theſe vegetable acids: They all contain, along with the acid, a great quantity of oleaginous particles, which would not fail to diſcolour the cloth. Beſides, the demand of the bleachfields would raiſe their price too high.

The mineral acids have neither of theſe objections. They are exceedingly cheap, and contain no oil, though many chymiſts have aſſerted that they did. I will freely own, that, at firſt, I had no great opinion of their ſucceſs from two reaſons; their want of all fermentation, which I then looked on as neceſſary; and their extreme corroſiveneſs. But the experience of two different ſummers, in two different bleachfields, has convinced me, that they will anſwer all the purpoſes of the milk and bran ſours ; nay, in ſeveral reſpects, be much preferable to them. I have ſeen many pieces of fine cloth, which had no other ſours, but thoſe of vitriol, and were as white and ſtrong as thoſe bleached in the common way. I have cut ſeveral webs through the middle, and bleached one half with milk, and the other with vitriol, gave both the ſame number of operations, and the latter were as white and ſtrong as the former.

The method, in which it has been hitherto uſed, is this. The proportion of the oil of vitriol to the water, with which it is diluted, is half an ounce, or at moſt three quarters of the former, to a gallon of the latter. As the milk ſours are diminiſhed in ſtrength, ſo ought the vitriol ſours. The whole quantity of the oil of vitriol to be uſed, may be firſt mixed with a ſmall quantity of water, then added to the whole quantity of water, and well-mixed together. The water ſhould be milk-warm ; by which means the acid particles will penetrate further, and operate ſooner. The cloth ſhould then be put dry into the liquor.

It is obſerved, that this ſour performs its taſk much ſooner than thoſe of milk or bran ; ſo that Mr. John Chryſtie, in making the trial, uſed to lay the milk ſours twenty-four hours before the vitriol. I am of opinion, that five hours will do as much with this ſour, as five days with the common ſort. But the cloth can receive no harm in allowing it to remain for ſome days in the ſour, but rather, on the contrary, an advantage, as we ſhall have occaſion afterwards to obſerve. The cloth is then taken out, well rinſed, and mill-waſhed in the ordinary way.

The liquor, while the cloth lies in this ſour, is leſs acid the ſecond day than the firſt, leſs the third than the ſecond, and ſo diminiſhes by degrees. At firſt it is clear, but by degrees a mucilaginous ſubſtance is obſerved to float in it, when put into a glaſs. This foulneſs increaſes every day. This ſubſtance extracted by the acid, is the ſame with what is extracted by the alkaline ſalts; and blunts the acidity of the former, as I have ſhown it does the alkaleſcency of the latter. This will appear more plain, when I come to ſhow the natural effects of theſe acid ſalts on unbleached cloth. Hence the liquor loſes, by degrees, its acidity. But as the acid ſalts do not unite ſo equally with oleaginous ſubſtances, as the alkaline do, the liquor is not ſo uniformly tinged in the former, as in the latter caſe, and the mucous ſubſtance preſents itſelf floating in it.

It is obſerved, that, in the firſt ſouring, which is the ſtrongeſt, the liquor, which was a pretty ſtrong acid before the cloth was put in, immediately afterwards becomes quite vapid; a proof how very ſoon it performs its taſk. But in the following operations, as the linen advances in whiteneſs, the acidity continues much longer; ſo that in the laſt operations the liquor loſes very little of its acidity. This happens although the firſt buckings, after the firſt ſourings, are increaſed in ſtrength, while the ſours are diminiſhed. There are two cauſes to which this is owing. The texture of the cloth is now ſo opened, that although the lyes are ſtrong, the alkaline ſalts and abſorbent earth are eaſily waſhed out; and the oleaginous particles are, in a great meaſure, removed, which help to blunt the acidity of the liquor.

I have heard two objections brought againſt the uſe of vitriol ſours. One is, That the proceſs of ſouring with milk is performed by a fermentation; and as there is no fermentation in the vitriol ſours, they cannot ſerve our purpoſe ſo well: the other, That they may hurt the texture of the cloth. The anſwer to the former objection is very ſhort, That the vitriol ſours operate ſucceſsfully without a fermentation, as experience ſhows; and therefore in them a fermentation is not neceſſary. The ſame objection might be made to ſtrike againſt the vegetable ſours, That as the mineral acids operate without fermentation, therefore the vegetable, which ferment, will not ſucceed; but the truth is, that both ſucceed. The vegetable liquors muſt ferment, that their acids may be ſet free; but the mineral acids neither ſtand in need, nor are capable of any ſuch change. This ſhows evidently, that all the advantage of fermentation is to diſengage the acid ſalts, that they may exert themſelves on the cloth.

As to the latter objection, That oil of vitriol, being a very corroſive body, may hurt the cloth; that will vaniſh likewiſe, when it is conſidered how much the vitriol is diluted with water, that the liquor is not ſtronger than vinegar, and that it may be ſafely taken into the human body. But there will remain no doubt of its ſafety, when I come afterwards to ſhew, that I have kept linen in a ſtrong ſour of vitriol for many months, and that the cloth was as ſtrong after it was taken out, as when it was put in. Theſe experiments convinced me of its ſafety, before I had experience of its uſe in the bleachfield.

That it may be uſed with ſafety, much ſtronger than what is neceſſary in the bleachfield, appears from the following experiment with regard to the ſtamping of linen. After the linen is boiled in a lye of aſhes, it is bleached for ſome time. After this, in order to make it receive the colour, it is ſteeped in a ſour of water and oil of vitriol, about fifteen times ſtronger than that made uſe of in the bleachfield; for to 100 gallons of water are added two and a half of oil of vitriol. Into this quantity of liquor, made ſo warm as the hand can juſt be held in it, is put ſeven pieces of 28 yards each. The linen remains in it about two hours, and comes out remarkably whiter. The fine cloth often undergoes this operation twice. Nor is there any danger if the oil of vitriol is well mixed with the water. But if the two are not well mixed together, and the oil of vitriol remains, in ſome parts, undiluted, the cloth is corroded into holes.

Let us now take a view of the advantages which the vitriol ſours muſt have over the milk. The latter is full of oleaginous particles, ſome of which muſt be left in the cloth: but the caſe is worſe if the ſcum is allowed to precipitate upon the cloth. The former is liable to neither of theſe objections.

The common ſours haſten very faſt to corruption; and if, from want of proper care, they ever arrive at that ſtate, muſt damage the cloth very much. As the milk is kept very long, it is often corrupted before it is uſed; and, without acting as a ſour, has all the bad effects of putrefaction. The vitriol ſours are not ſubject to putrefaction.

The milk takes five days to perform its taſk; but the vitriol ſours do it in as many hours; nay, perhaps, in as many minutes. Their junction with the abſorbent particles in the cloth muſt be immediate, whenever theſe acid particles enter with the water. An unanſwerable proof that the fact is ſo, ariſes from the circumſtances which happen when the cloth is firſt ſteeped in the vitriol ſour; the cloth has no ſooner imbibed the acid liquor than it loſes all acidity, and becomes immediately vapid. This effect of vitriol ſours muſt be of great advantage in the bleachfield, as the bleachers are at preſent hindered from enjoying the ſeaſon by the tedioufneſs of the ſouring proceſs. The whole round of operations requires ſeven days; to anſwer which they muſt have ſeven parcels, which are often mixing together, and cauſing miſtakes. As three days, at moſt, will be ſufficient for all the operations when vitriol ſours are uſed, there will be no more than three parcels. The cloth will be kept a ſhorter time in the bleachfield, and ſo arrive ſooner at market.

The milk ſours are very dear, and often difficult to be got; but the vitriol are cheap, may be eaſily procured, and at any time.

There is yet another advantage in the uſe of vitriol, and that is its power of whitening cloth. It will appear, afterwards, by experiments, that, even in this diluted ſtate, its whitening power is very conſiderable. We have already ſeen that it removes the ſame colouring particles which the alkaline lyes do. What of it then remains, after the alkaline and abſorbent particles are neutralized in the cloth, muſt act on theſe colouring particles, and help to whiten the cloth. That this is really the caſe, appears from the following fact. Mr. Chryſtie being obliged to chuſe twenty of the whiteſt pieces out of a hundred, five of the twenty were taken out of ſeven pieces which were bleached with vitriol.

From both experience and reaſon I muſt then give it as my opinion, That it would be for the advantage of our linen manufacture, to uſe vitriol in place of milk ſours.

SECT. V.

Hand-rubbing with ſoap and warm water, rubbing-boards, ſtarching, and bluing.

AFter the cloth comes from the ſouring, it ſhould be well waſhed in the waſhing-mill, to take off all the acid particles which adhere to its ſurface. All acids diſcompoſe ſoap, by ſeparating the alkaline ſalts and oily parts from one another. Were this to happen on the ſurface of the cloth, the oil would remain; nor would the waſhing-mill afterwards be able to carry it off.

From the waſhing-mill the fine cloth is carried to be rubbed by womens hands, with ſoap and water. As the liquors which are generally employed for ſouring, are impregnated with oily particles, many of theſe muſt lodge in the cloth, and remain, notwithſtanding the preceding milling. It is probable, that all the heavy oils are not evaporated by bleaching. Hence it becomes neceſſary to apply ſoap and warm water, which unite with, diſſolve, and carry them off. It is obſerved, that if the cloth, when it is pretty white, gets too much ſoap, the following bleaching is apt to make it yellow: on that account they often wring out the ſoap. I believe it would be proper to give it always a milling with warm water, before bucking, to take out the ſoap and looſened dirt more effectually. The preceding fact is a ſtrong argument in its favour.

It is a matter worth inquiring into, whether hard or ſoft ſoap is beſt for cloth. Moſt bleachers, I think, agree, that hard ſoap is apt to leave a yellowneſs in the cloth. I have been told, that the uſe of hard ſoap is forbidden in Holland. As there muſt be a conſiderable quantity of ſea-ſalt in this kind, which is not in the ſoft, and as this ſalt appears prejudicial to cloth, I would prefer the latter.

The management of the coarſe cloth is very different, in this operation, from the fine. Inſtead of being rubbed with hands, which would be too expenſive, it is laid on a table, run over with ſoap, and then put betwixt the rubbing-boards, which have ridges and grooves from one ſide to another, like teeth. Theſe boards have ſmall ledges to keep in the ſoap and water, which ſaves the cloth. They are moved by hands, or a water-wheel, which is more equal, and cheaper. The cloth is drawn, by degrees, through the boards, by men who attend; or, which is more equal, and cheaper, the ſame water-wheel moves two rollers, with ridge and groove, ſo that the former enters the latter; and, by a gentle motion round their own axis, pull the cloth gradually through the boards.

This mill was invented in Ireland about thirty years ago. The Iriſh bleachers uſe it for their fine, as well as coarſe cloth. However neceſſary it may be for the latter, on account of its low price, I ſee no reaſon, on that account, for uſing it to the former. Theſe rubbing-boards were forbidden, ſome years ago, in Ireland, by the Truſtees for the manufactures of that country, convinced from long experience of their bad effects. But as proper care was not taken to inſtruct the bleachers, by degrees, in a ſafer method, they continued in the old, made a party, and kept poſſeſſion of the rubbing-boards. There were conſiderable improvements made in them in this country; ſuch as the addition of the ledges, to keep the cloth moiſt; and of the rollers, which pull the cloth more gradually than mens hands. Theſe improvements were firſt made in Salton bleachfield.

The objections againſt theſe rubbing-boards, I think, are unanſwerable. By rubbing on ſuch an unequal ſurface, the ſolid fibrous part of the cloth is wore; by which means the cloth is much thinned, and, in a great meaſure, weakened, before it comes to the market. As a proof of what I ſay, if the water which comes from the cloth in the rubbing-boards, is examined, it will be found full of cottony, fibrous matter. Theſe boards give the cloth a cottony ſurſace, ſo that it does not keep long clean. Again, they flatten the threads, and take away all that roundneſs and firmneſs, which is the diſtinguiſhing property of cloth bleached in the Dutch method.

For theſe reaſons I am of opinion, that they are entirely prejudicial to fine cloth; and hope they will not be employed in this country to it, as I know they ſtill are by many bleachers who follow the Iriſh method. As they ſeem to be, in ſome meaſure, neceſſary to render the expence of bleaching coarſe linen leſs, they ought never to be uſed above twice, or thrice at moſt. They might, I think, be rendered much more ſafe, by lining their inſides with ſome ſoft elaſtic ſubſtance that will not wear the cloth ſo much as the wooden teeth do. I am told Mr. Chryſtie at Perth has lined his boards with ſhort hair, for ſome years, and finds that it anſwers very well.

After the coarſe linen has undergone a rubbing, it ſhould be immediately milled for an hour, and warm water poured now and then on it to make it lather. This milling has very good effects; for it cleans the cloth of all the dirt and filth which the rubbing-boards have looſened, and which, at the next boiling, would diſcolour the cloth. Beſides, it is obſerved, that it makes the cloth leſs cottony, ~~and more~~ firm, than when whitened by rubbing alone.

The laſt operation is that of ſtarching and bluing. It often happened, that the cloth, when expoſed to the weather to be dried after this operation, got rain; which undid all again, and forced the bleacher to a new expence. To remedy this inconvenience, Mr. John Chryſtie, ſome years ago, invented the dry-houſe, where the cloth may be dried, after this operation, in any weather. This invention meets with univerſal approbation.

PART

PART III.

SECT. I.

Blue pearl aſhes.

THE ſalts or aſhes are the principal agents uſed by the bleacher; and therefore merit our conſideration. A phyſician who underſtood not the compoſition of the medicines he uſed, would be reckoned ignorant: and why not the bleacher who uſes inſtruments unknown to him? His ignorance, however, is not blameable. The utmoſt ſkill in his art cannot teach him to analyſe theſe aſhes into their conſtituent parts. For that knowledge he muſt depend on chymiſtry, which, operating in the gentle method of ſolution and evaporation, preſents to us the natural conſtituent parts of bodies. The force of ſtrong chymical fire muſt alter theſe. A heat as gentle as the ſummer ſun, cannot.

This analyſis, by diſcovering to us the conſtituent parts of theſe ſalts, will teach us the way of compounding and manufacturing them at home, of procuring them perhaps at a cheaper rate, and not depending on foreign countries for what is abſolutely neceſſary in carrying on our home manufactures. It will be attended with another advantage. As the bleaching aſhes of the ſame name differ very much in ſtrength from one another, this analyſis will teach the bleacher how to examine them; how to diſcover the quantity of ſalts in them; and, conſequently, to aſcertain their value and uſe. It will ſhow him how to diſcover the qualities of a new ſalt.

Let us imitate the mathematicians in their method of inveſtigating truth. Let us ſet out entirely ignorant of the nature, properties, or compoſition of theſe different ſalts; and, by the help of ſome data, or uncontroverted concluſions from eſtabliſhed experiments, proceed to their examination.

The blue pearl aſhes are of a light bluiſh colour; have a hot and pungent taſte; and diſſolve in the mouth.

Exp. 13. In order to diſcover what effect acids would have on theſe aſhes, and what quantity of the former the latter would deſtroy; from which I might be able to form ſome judgment of the quantity and ſtrength of the ſalt they contained; I took a drachm of blue pearl aſhes, and poured on it a mixture of one part ſpirit of nitre, and ſix parts water; which I ſhall always afterwards uſe, and call the acid mixture. An efferveſcence aroſe, and, before it was finiſhed, 12 tea-ſpoonfuls of the mixture were required. This effervеſcence with each ſpoonful of the acid mixture was violent, but did not laſt long. A reddiſh powder was precipitated to the bottom. When ſaturated, it had a nitrous taſte.

It is proper here to give a caution. This experiment does not afford a certain concluſion, either as to the proportion or ſtrength of the real alkaline ſalts which theſe aſhes contain; as there are other bodies beſides alkaline ſalts, that effervеſce with acids, ſuch as abſorbent and calcarious earths, and quick-lime. No certain concluſion can be drawn, unleſs we were certain, that none of theſe bodies were mixed with the aſhes; which we cannot be, until we have performed the proper trials, fit for diſcovering the preſence of theſe different bodies.

Exp. 14. To ſeparate the pure ſaline from the earthy part of theſe aſhes, a half-pound of blue pearl was mixed with three Engliſh pints of water, and put over the fire. The ſalt was diſſolved when the water was milk-warm. The ſolution, tried ſeveral ways, gave me no ſigns of containing any ſulphur. It was ſtrained through brown paper, and left in it a reſiduum, that weighed, when dried, 3 gr. By another experiment I got a much greater quantity of earthy ſubſtance. The ſtrained ſolution was afterwards boiled into 3 gills, and ſet in a cellar that I might diſcover if there was any nitre, ſea ſalt, or any other kind of ſalt mixed with the aſhes. Theſe ſalts will diſcover themſelves by their cryſtalliſation. After the liquor had ſtood a fortnight, there appeared at the bottom of the cup, ſome cryſtals that ſeemed to be much akin to the tartarus vitriolatus. Some of the alkaline ſalts, and a white powder like the reſiduum, had mixed with theſe cryſtals. This neutral ſalt will likewiſe fall to the bottom of the cup, when the ſolution is near evaporated. The liquor being evaporated, gave me 5½ oz. of ſalt.

This ſalt was much of the colour of the white pearl aſhes; it had loſt all its former pellucidity, and was brown on the top, and white beneath. The taſte was much the ſame as before. When half an hour from the fire, it began to turn moiſt.

Exp. 15. To try the ſtrength of theſe ſalts, I diſſolved half a drachm in a ſpoonful of water, and added the acid mixture to it. During the effervеſcence a whitiſh powder fell to the bottom. Four tea-ſpoonfuls of the acid completed the ſaturation. The liquor being evaporated, gave a nitre.

By this experiment it appears, that the ſalts extracted by boiling from the aſhes, are not ſo ſtrongly alkaline, as the aſhes themſelves; and that the boiling, by ſeparating their component parts, which appears by their loſs of weight, and precipitation of a powder, weakens them. This ought to teach bleachers not to boil thoſe ſalts, that are eaſily diſſolved in water without boiling, for by that means they weaken them conſiderably, but to add them to the lye when cooling.

The reſiduum which remained in the brown paper being dried over the fire, taſted and looked like chalk, had no ſaline pungency, nor was diſſolvable in the mouth.

Exp. 16. To three quarters of this I added the acid mixture; a ſtrong effervеſcence enſued, and a half tea-ſpoonful was conſumed before it ceaſed.

It appears from this experiment, that this earth has as ſtrong a power of deſtroying acids, as the ſalts themſelves. Is this earth, then, the only abſorbent or alkaline part in the compoſition of alkaline ſalts? Has their other conſtituent part or parts, rendered volatile, or changed, by boiling, no oppoſition to acids? So it would ſeem. I ſhall conſider this earthy part more fully in the next ſection.

The concluſion, then, that we draw from the foregoing experiments, is, That the blue pearl aſhes are a very pure alkaline ſalt with a ſmall proportion of vitriolated tartar, and abſorbent earth.

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SECT. II.

White pearl aſhes.

THEY are of a white colour, diſſolvable in the mouth, hot and pungent.

Exp. 17. To a drachm of the white pearl aſhes, I added the acid mixture. An efferveſcence aroſe, which laſted till the ſalts had deſtroyed ten tea-ſpoonfuls. When ſaturated, it had a nitrous taſte, and a white powder at the bottom. Theſe aſhes, then, are a fifth part leſs antacid than the laſt.

Exp. 18. To diſcover the proportion of their earthy part to their ſaline, half a pound was put into three Engliſh pints of water; which diſſolved when the water began to turn warm; but not juſt ſo ſoon as the blue pearl aſhes. The ſolution gave no ſign of containing ſulphur. When ſtrained, I got 50 grains of reſiduum. It was afterwards boiled into three gills, and ſtood fourteen days in a cellar. I diſcovered ſome tartarus vitriolatus, and a good deal of a white powder, like the reſiduum which had fallen to the bottom. The ſolution evaporated, gave me of pure ſalt 5 oz. and 7 dr.

This ſalt was brown above, and white beneath; and, as I thought, had ſcarce ſo pungent a taſte as before boiling. It began to diſſolve in the air, when it had been half an hour from the fire.

Exp. 19. Half a drachm was diſſolved in a ſpoonful of water. They ſeemed more difficult to be diſſolved than the ſalts of the blue pearl. The ſolution took four tea ſpoonfuls of the acid mixture to ſaturate it, and let fall a copious white powder, as the ſalts of the blue pearl had done.

The reſiduum is darker-coloured, than that of the blue pearl; but has much the ſame chalky taſte.

Exp. 20. I put ſix grains of it in a glaſs, and poured two tea-ſpoonful of water on it. A half tea-ſpoonful of the acid mixture raiſed a ſtrong efferveſcence, and ſaturated it.

Exp. 21. I put into a reverberatory furnace ſome of the reſiduum. After it had been there two hours, it had not the taſte of lime, nor afforded me a lime-water. Alkaline ſalts, each time that they are boiled, and ſtrained, leave a ſimilar earth behind them; and, if the operation be continued, the whole may be converted into this earth. If ſalts are kept long in fuſion, they are turned, at laſt, into the ſame earth *. I got ſome of this earthy matter from pearl aſhes, which were ſtrained through brown paper before they were boiled, but could not reduce that earth to quick-lime by the force of a reverberatory furnace. This earth, then, is the fixed baſis of alkaline ſalts; and appears, by theſe experiments, to be of an abſorbent, and not a calcarious nature, as all the chymiſts,

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* Junker de ſalib. alkal. fix. p. 372.

miſts, ſo far as I know, have univerſally called it. Let us now try to diſcover the other volatile principle, or principles, that were joined to this earthy baſe in the compoſition of alkaline ſalts.

There are two different opinions with regard to the formation or origin of theſe alkaline ſalts. The former is, That they pre-exiſt in vegetables in the ſame form, and are ſeparated from the other parts, by incineration *. This opinion is now univerſally exploded, as no ſuch ſalt has ever, without the aſſiſtance of fire, been diſcovered in plants, though it is found elſewhere. The other opinion is, That they are produced, by the act of combuſtion, from ſome new combination of the parts of the plant, that were not combined before. This is the opinion of Stahl, Boerhaave, Junker, and almoſt all the chymiſts. They ſeem not to be agreed, however, as to the principles that go to their compoſition. Stahl imagines they ariſe from a junction of the heavy inflammable part with the ſaline. From the known experiments of making alkaline ſalt from nitre and any inflammable body, he draws this concluſion. "Item, itaque hoc in vegetabilium incineratione contingere, et ita alkalia illorum nihil aliud eſſe quam partem illorum nitroſam, cum bituminoſa deflagrando commixtam, ſequentia phænomena confirmant †." Junker differs from Stahl

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* Burning to white aſhes.

† Art. 3. de ſal. volat. plantar. fund. chym. A book publiſhed by one of his ſcholars; and though

Stahl, in aſſociating the inflammable, acid, and terrene parts together: "Sub ingenti autem illarum commotione, pars acida ex mixtione ſua ibidem reſolvitur, et terrenis partibus illiditur; cum quibus, ſi cum fixiore ſulphurea firmiter complicatur, generat et conſtituit ſubſtantiam illam alkalinam fixam *." The arguments produced by them in proof of an inflammable principle, do not ſeem to me, to be ſufficient. The argument that Stahl brings in defence of his opinion, is this. If a plant, which affords plenty of alkaline ſalt, be dried, bruiſed, and digeſted in ſpirit of wine, until all the reſinous part be extracted, then burnt in a gentle fire, (leni igne), it will afford a nitrous ſalt, but not an alkaline one; becauſe, ſays Stahl, the reſinous part that ſhould go to its compoſition, is carried off. This concluſion of Stahl ſeems to me too ſtrong. It proves that an inflammable principle is neceſſary to the production of an alkaline ſalt, but it proves no more. To ſay that it is neceſſary in the compoſition, is ſaying more than the experiment will allow. The inflammable principle is abſolutely neceſſary in the production of alkaline ſalts, in order to make a great commotion and heat in the vegetable, by which alone the acid parts are to be driven off. A gentle external fire, after the oil which is the ſupport of the internal fire is withdrawn, can never be ſufficient for this purpoſe. Chymiſts have obſerved, that

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though not by himſelf, yet with his connivance.

[*] De ſalibus alkalinis fixis, tab. 66.

that a ſmothered fire produces little or no alkaline ſalt. This ſhews a flame to be abſolutely neceſſary.

This reaſoning ſerves, likewiſe, as an anſwer to the experiment mentioned before, by which an alkaline ſalt is produced from nitre and an inflammable body. Junker has another argument in ſupport of an inflammable principle. " If," ſays he," an alkaline ſalt ſaturated with " diſtilled vinegar is again expoſed to the fire, " it gains a black colour, which is an undoubted " proof, that it contains a heavy, inflammable " ſubſtance." Undoubted I'll allow it to be; but whence comes it? From the diſtilled vinegar, to be ſure, which contains a heavy oil in conſiderable quantity.

Theſe experiments, therefore, are ſufficient to prove the exiſtence of an inflammable principle in alkaline ſalts. But the experiments that prove the contrary, are very ſtrong. Whatever body contains an inflammable principle, deflagrates with nitre in fuſion; but alkaline ſalts do not. Whenever alkaline ſalts and an inflammable body are joined, they emit, when the mineral acids are poured over them, a ſulphureous ſmell; but alkaline ſalts do not. When an oleaginous ſubſtance is joined to alkaline ſalts, a ſubſtance different from either, called Soap, is formed. The chymiſts themſelves acknowledge that all alkaline ſalts may be formed of two bodies, neither of which contain an inflammable oleaginous principle. Theſe quotations from Stahl, ſhow how much he differs from himſelf. Fund. chym. part. 2. P. 50. " Calx viva, vel cum vitriolo,

" vel ſale communi, aut ſpiritu acido, mixta et " calcinata, præbet ſal fixum accerrimum, ſolubile. P. 52. " Sic ſpiritus acidus ſalis cum " creta mixtus, mutatur in ſal alkali fixum. Ibid. P. 54. " Nempe ſpiritus acidus ſalis commixtus cum creta, coral. uſt. calce viva, tranſmutatur in ſal alkali, quod eoſdem effectus " præbet in ſolutionibus et præcipitationibus " cum ſale quodam fixo alkalino." Theſe experiments, if he has performed them, ſhow plainly, that an inflammable principle is not neceſſary. But I muſt own, that theſe experiments, though they make againſt the theory I have been endeavouring to refute, did not ſucceed with me, as they have done with Stahl.

I ſhall relate what ſucceſs I have had in theſe experiments. In the firſt quotation he orders the neutral body, made of quick-lime and the ſpirit of ſalt, to be calcined; and though he does not mention calcination in the two laſt, it muſt be underſtood; for otherwiſe the bodies ſaturated would be neutral, and not alkaline.

Exp. 22. Two ſcruples of chalk being fully ſaturated with ſpirit of ſea ſalt, gave a yellow, bitter, pungent liquor. This, when dried, and put immediately into a gentle fire for ſome minutes, gave no ſigns of efferveſcing with acids, but attracted the moiſture ſtrongly. It was again put into a crucible, and ſet in the middle of a kitchen-fire, for two hours. Still it raiſed no efferveſcence with acids; but had ſome of the other properties of alkaline ſalts, ſuch as turning moiſt in the air, diſſolving in water, and turning ſyrup of violets green. It was afterwards put into a reverberatory furnace for an hour and a half;

but by this heat it ſeemed to have been turned into glaſs; for there was nothing to be found in the crucible, and its bottom had a glazed-like appearance. Thus a calcarious earth, invitreſcible before, is turned, by the addition of an acid, into glaſs.

Exp. 23. Two ſcruples of quick-lime were ſaturated with ſpirit of ſea ſalt, which produced a yellow cauſtic liquor, that burnt the tongue when applied to it. Being evaporated, and kept in the kitchen-fire for two hours, I got a ſubſtance that ſcarcely diſſolved in water, nor in the leaſt efferveſced with acids; but turned ſyrup of violets green, and taſted juſt like alkaline ſalts. It was put for an hour and a half in a reverberatory furnace, and I had 22 gr. of a gritty undiſſolvable ſubſtance. Thus the acid has changed the calcarious baſe into an earthy ſubſtance, that is of a different nature from quick-lime.

I purſued theſe trials further, to ſee if I could ſucceed better with the other mineral acids.

Exp. 24. Chalk was ſaturated with ſpirit of nitre, and then put into a kitchen-fire for half an hour. I got a ſubſtance which was undiſſolvable in water, and to me appeared to be like chalk.

Exp. 25. Quick-lime ſaturated with the ſpirit of vitriol, afforded a bitter cauſtic liquor, which excoriated my tongue. When evaporated, it was put into the kitchen-fire for an hour. I got a brown ſubſtance, which was a little hot in the mouth, did not appear to be diſſolvable in water, and afforded a lime-water.

From theſe experiments it appears, that a ſubſtance formed of an acid ſalt and abſorbent earth, has ſome of the properties of alkaline ſalts, while

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it wants others. The chymiſts, for they generally follow Stahl in this opinion, have been led aſtray by the cauſtic taſte of the production. Notwithſtanding the ill ſucceſs of theſe experiments to prove that alkaline ſalts are a compound of an abſorbent earth and an acid, yet I ſtill think there is a great degree of probability on that ſide of the queſtion, from the following reaſons.

Thoſe plants which contain no acid, afford no alkaline fixed ſalt, ſuch as onions, muſtard, &c. If ſuch plants as contain an acid, are diſtilled, and the acid forced over with a ſtrong fire, they afford leſs alkaline ſalt. Alkaline ſalts are made more alkaline by a ſtronger heat than what was uſed before; which ſhows, that more of the acid has been driven off by the fire. "Nitre, "without any addition, kept long in fuſion, "acquires a cauſtic alkaline nature*." There are ſcarce any of the properties of alkaline ſalts, but what belong either to the abſorbent earths, or acids. To the former they owe their fixedneſs in the fire, their attraction and effervеſcence with acids, with all the properties that depend on this cauſe, and their power of turning the ſyrup of violets green: to the latter, their cauſtic power, their ſolubility in water, their tranſparency when diſſolved in it, their attraction of moiſture, their junction with oils, and their vitreſcency. If there are any particles of fire added to, and fixed in the alkaline ſalts, as it is probable there may be, theſe may a little vary ſome of the properties: As for inſtance, alkaline ſalts attract acids with a greater force, than abſorbent earths do, though the laſt deſtroy a greater quantity. This ſtronger attraction in alkaline ſalts may be owing to their parts being more opened, than thoſe of the earth, to the junction of ſome particles of fire, or, perhaps, to the remaining acid particles, between whom and the other acid there may be an attraction. This doctrine will receive an additional ſtrength, by conſidering, out of what ſubſtance or ſubſtances, pre-exiſting in the plant, thoſe alkaline ſalts are formed.

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* Junker de ſalib, alkal. fix.

The general opinion of chymiſts, as I mentioned before, is, that they are formed by a new combination of principles during combuſtion. I imagine they are formed by a ſeparation. The eſſential ſalts of plants ſeem to be the product of an acid, and an abſorbent earth; for theſe two, as we have ſhewed before, are ſufficient to make a neutral ſalt. There is no fact, I think, more clearly proved, than that there are acid particles continually circulating, in greater or leſs quantity, with the air. I have tried the aſhes of plants, and I find they contain a great quantity of abſorbent particles. Hence, then, the eſſential ſalts of vegetables. But theſe ſalts extracted, cryſtaliſed, and calcined by themſelves, afford, as Boerhave informs us, an alkaline ſalt. Why not likewiſe when the vegetable is burnt? This is the moſt natural way of accounting for their origin, without flying to new combinations during combuſtion. The fire will evaporate all the water, diſpel the greateſt part of the acid from theſe neutral ſalts; and there will remain a ſmall quantity of pure ſolid acid, joined to an abſorbent earth *, with, perhaps, ſome particles of fire in the compoſition.

SECT. III.

Muſcovy or blanch aſhes.

THE bulk of mankind are led by names. That two ſubſtances enjoy the ſame denomination, is enough, to the careleſs obſerver, to rank them in the ſame claſs, and to imagine their compoſition and qualities, in general, much alike: elſe how would the Muſcovy aſhes have ever been claſſed with thoſe above explained, when the external ſenſes, without further help, might, if attended to, have diſcovered the fallacy, and ſhown theſe to be of a very different nature from the two former?

Muſcovy

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* Long after theſe papers were wrote, I diſcovered the ſame opinion, with regard to the compoſition of alkaline ſalts, in the writings of a celebrated chymiſt, *Homberg des principes de chymie en general.* ——*Memoires pour l' annee* 1702.

Ces ſels fixes lixiviels ne ſont autre choſe qu'un reſte des ſels acides, que le feu de la calcination n'a pu ſeparer de la terre du mixte, qui lui ſert de baſe, et qui ſe diſſolvent enſemble dans l'eau commune.

The following quotation from the ſame diſſertation, appears to be an experimental proof of this Doctrine. *La ſeconde occaſion ou ces ſels fixes peuvent devenir volatils, eſt de les deſſoudre dans de l'eau, le tenir pendant quelque temps en digeſtion, enſuite de les filtrer et evaporer, puis recommencer ces operations pluſieurs fois, juſque à ce qu' à la fin ces ſels ſe cryſtalliſent; alors il le faut meler avec du bol, et les deſtiller à grand feu, il en viendra une eſprit acide: les ſels fixes retires de la tete-morte traite de la même maniere en rendra encore un peu, mais en três petite quantité.*

Muſcovy aſhes have very much the appearance of ſlaked lime; and are, like it, friable betwixt the fingers. The tongue, when applied, adheres to them. The firſt taſte which one perceives, is that of an alkaline ſalt? but this goes ſoon away, and leaves a ſtrong taſte of lime, which is peculiar to this ſalt. They never turn moiſt in the air; which plainly diſcovers, that they contain little alkaline ſalt. Some ſmall bits of charcoal are to be ſeen in their compoſition.

Exp. 27. On the addition of the acid mixture to a drachm of Muſcovy aſhes, there aroſe an ebullition, which, though it was not violent, yet continued long after the acid was joined to it. When they had got 4 ſpoonfuls, I took out a little piece to break it; and to the taſte it ſeemed inſipid, and gritty like a ſtone. They conſumed 17 tea-ſpoonfuls. When the ſaturation was fully completed, it taſted bitter, and very different from the two former ſalts.

Exp. 28. To ſeparate the ſalts from theſe aſhes, I put half a pound in two pounds of water, and kept it pretty warm over the fire, but did not let it boil, for fear of diſſipating the volatile parts, if there were any, till I thought the ſalts would be diſſolved; then I poured off the water. A half-pint was added to the remaining powder, which, after boiling ſome minutes, was likewiſe poured off. It was treated twice more in the ſame way. The laſt that came off was not ſalt, but had a taſte like lime-water. The decoction all together, when ſtrained, was about three pints. Though carefully examined, it gave no ſign of containing ſulphur. After

ter all was ſtrained, there remained in the paper 5½ dr. of a whitiſh powder, which added to 2 oz. 5 dr. of undiſſolvable ſubſtance, that lay at the bottom of the pot, when the water was poured off, made in all 3 oz. 5½ dr. This decoction boiled into half a pint, and ſet for a fortnight in a cellar, gave no ſign of any other ſalt. When all the water was evaporated, I had 10 dr. 15 gr. of a very cauſtic ſalt, which ſeemed lighter than the ſalts of the blue and pearl aſhes, and turned very moiſt, when kept from the fire twenty-four hours.

It appears that 3 oz. 18 gr. have been rendered volatile by the water, a greater quantity than in any of the two former ſalts. This loſs of ſubſtance probably ariſes from the watery parts contained in theſe aſhes.

Exp. 29. To aſcertain the ſtrength of theſe ſalts, I diſſolved half a drachm in water. The acid mixture produced a ſtronger efferveſcence than with the former ſalts; and four and a half tea-ſpoonfuls of it were required to ſaturate it. A browniſh powder fell to the bottom of the glaſs in great quantity. Theſe ſalts, then, appear to be ſtronger antacids than the former two, by their greater ebullition, and the greater quantity of acid they conſumed. If we are to judge by the laſt article, their proportionate antacid ſtrength (for this experiment may be no rule as to their other qualities) is as nine to eight. It appears likewiſe, that the antacid quality of the aſhes themſelves is almoſt double to that of the ſalts. Can this be owing to the volatility of ſome acid parts? or to the greater antacid power of the other part that is mixed with theſe ſalts? This laſt appears probable from the following experiments, which diſcover a ſtronger antacid power in the reſiduum than in the ſalts.

Let us now examine the reſiduum, which, as I mentioned before, was of two ſorts; what remained in the bottom of the pot, and what remained in the gray paper. The firſt was of a light brown colour, and run together into hard pieces; the latter was white, and a powder.

Exp. 30. Thirty grains of the latter effervefced ſtrongly with the acid mixture, and conſumed five and a half tea-ſpoonfuls. Thus, though the reſiduum appears ſtronger than the ſalts, yet it ſeems much weaker in its antacid power than the aſhes.

I poured water on a quantity of both reſiduums in two different cups, and let it ſtand all night. The water had a taſte of chalk and water, next morning, but not of lime-water.

This ſubſtance might ſtill be calcarious, though it had no parts now ſoluble in water; for the reiterated boiling in water might have carried off theſe ſoluble parts, as we know it does. My next trial, therefore, was, to ſee if I could reduce it to quick-lime again, by the force of the fire. There is no doubt but that the fire will reduce into quick-lime, at a ſecond trial, thoſe calcarious parts, which had not got a ſufficient fire the firſt time, and on that account were not calcined into quick-lime. We often ſee undiſſolved in the water pieces of lime-ſtone, which would have been reduced to quick-lime had they got ſufficient fire. But whether thoſe parts of quick-lime, which have been ſufficiently calcined, and have been robbed of all thoſe particles that are ſoluble in water, can again be reduced to quick-lime, is not, I think, clearly aſcertained by authors who have wrote on this ſubject.

Exp. 31. To determine this queſtion, I tried the following experiment. A conſiderable quantity of quick-lime was quenched in water, ſo that it roſe ſome inches above the lime. The whole was often ſtirred about. After it was completely ſettled, I took off the ſurface of the lime, which was compoſed of thoſe particles that had been the longeſt ſuſpended in water, and of courſe the fineſt. This lime, that could have no particles in it but what had been ſeparated by the water, and therefore none but thoſe that had been changed into quick-lime by the fire, was boiled in water until it no longer taſted like lime-water. This took two days boiling. The effœte lime was then put into a reverberatory furnace, for an hour and a half. This reduced it again to ſtrong quick-lime; for it ſucked up the water very greedily, fell down into powder, and afforded a ſtrong lime-water with a pellicle.

Exp. 32. Some of the reſiduum of the white Muſcovy aſhes, put in a ſtrong kitchen-fire for two afternoons, and afterwards mixed with water, did not fall; after it had ſtood ſome time, the water had no pellicle, nor a taſte of lime-water, but as if chalk and water had been mixed together.

But the ſame ſubſtance, kept in a reverberatory furnace for an hour and a half, gave me a ſtrong lime-water with a pellicle. The reſiduum then appears to be the caput mortuum of quick-lime.

Exp. 33. Another experiment of the ſame kind I tried at the bleachfield. I took ſome of the caput mortuum, which remains in the copper after the lye is taken off, and will not diſſolve in water. It had no taſte but that of an earth. It was calcined in a large ſtrong fire for two hours; when cold water was poured on it, which made an ebullition, and cauſed it to fall down. When the liquor had ſtood all night, it had the pellicle and taſte, though not very ſtrong, of lime-water.

Let us ſee if we cannot make a lime-water from the Muſcovy aſhes, without the aſſiſtance of fire.

Exp. 34. Two ounces of them were waſhed, by continual addition of freſh water, till the water that came off from them had no longer a ſalt taſte. Then I poured ſome water over them, and let the mixture ſtand all night. Next morning it had the pellicle of lime-water; and appeared, on taſting, to be good lime-water.

As a further proof, we could have diſtilled ſome of the aſhes, after the ſalts had been waſhed out, with crude ammoniac ſalt, and ſeen whether the volatile ſpirit was like that produced from lime and that ſalt; for a ſpirit produced in this way, is found to differ very much from a ſpirit produced by an alkaline ſalt in place of lime. But my ingenious friend Dr. Cullen has prevented me; and, having diſtilled Muſcovy aſhes and ſal ammoniac together, got ſuch a ſpirit as is procured from the latter and quick-lime. By this experiment he made it highly probable, that lime entered into the compoſition of the Muſcovy aſhes; and is, therefore, juſtly intitled to the merit of being the firſt diſcoverer.

From theſe experiments the following corollary follows, That the Muſcovy aſhes contain an alkaline ſalt and lime; and the latter in much greater proportion than the former.

SECT IV.

Caſhub aſhes.

THESE aſhes are extremely hard, of the colour of iron ſtone, with many ſhining particles, and ſome pieces of charcoal in them. They have a ſaline taſte, with a conſiderable degree of pungency. They feel gritty in the mouth, when broke in pieces by the teeth; for they will not diſſolve.

Exp. 35. When the ſaline mixture was poured over them, they did not efferveſce violently, but long; and the liquor had a very black powder on the top and bottom. They emitted a ſulphureous ſmell; and, when the ſaturation was completed, which was done by 13 tea-ſpoonfuls of the acid mixture, they had a ſulphureous taſte.

Exp. 36. To extract the ſalts, a half-pound was boiled in a pint of water; then the water poured off, and a half-pint put on the aſhes again; and ſo on till the water taſted no longer ſalt. This boiling took twenty-four hours. The laſt that came off had a ſtrong taſte of ſulphur, and was blackiſh.

Exp. 37. To try if there was any ſulphur in the decoction, I put a piece of ſilver into it; which in a few minutes was turned almoſt quite black.

Exp. 38. This experiment corroborates the former. Into 1 oz. of the decoction I poured as much ſpirit of nitre as ſaturated it. During the addition of the ſpirit there was a ſtrong ſmell of a volatile ſulphur. The liquor turned lacteſcent, and let fall to the bottom a light-coloured powder in conſiderable quantity. I ſtrained the whole through brown paper; and there was left in it a ſulphureous ſmelling ſubſtance, which, when dried, weighed one fourth of a grain. This ſubſtance, when burnt, on a red-hot iron, had not a blue, but pale-red flame, and a very gentle ſmell of burnt ſulphur. As this is a vegetable ſulphur, that is to ſay, an inflammable body joined to a vegetable, and not a mineral acid; it probably differs from the mineral ſulphur in the ſtrength of its qualities, and, therefore, may not have ſuch a ſtrong ſmell as the latter.

Let us try if we can aſcertain the quantity of this ſulphureous matter in the decoction. It is very volatile, and therefore cannot be caught, ſo that we might weigh it. Let us take its power in colouring ſilver, and ſee what light it will afford us in this intricate ſcrutiny. The leſs the quantity of ſulphur, the weaker the colour. I took 3 gr. of ſulphur, opened by an alkaline ſalt, and diluted it ſo with water, that the ſolution had loſt all taſte, and took two hours to alter the colour of ſilver in a ſmall degree. The quantity of water uſed was five pints. When two pints more were added, it loſt altogether this quality. To apply this experiment to the preſent queſtion,

Exp. 39. I diluted a ſmall quantity of the decoction, ſo that it took the ſame time to have the ſame effect, as in the former trial. The proportion of water to the decoction was, as 192 to 1. There were three pints of the whole; therefore 192 multiplied by 3, gives the quantity that could be made out of the whole decoction of this weak ſulphurated mixture, which is 576 pints. So that dividing the number of pints by 5, and then multiplying them by 3, we have the number of grains of ſulphur in this decoction. The whole then is 5 dr. 35 gr. and about a half, in the decoction, beſides what remains in the reſiduum, which ſeems to be more. Every bleacher, if he extracts all the ſalts from the Caſhub aſhes, muſt have that quantity of ſulphur from each half-pound of the aſhes; and if he boils them longer, he will probably have more. The only objection to this reaſoning is, That we have argued from a mineral ſulphur to a vegetable one, and ſuppoſed their powers of tinging ſilver to be the ſame. As I cannot poſitively aſſert them to be the ſame, I muſt allow this objection to have ſome weight; though it is probable there may be little difference betwixt them in this quality.

When the decoction was boiled into a gill and a half, it did not turn ſilver black more ſpeedily than before boiling; which ſhows the ſulphur to be as volatile as the water. This quantity ſtood for ſome days in a cellar, but no ſign of any cryſtalliſation. It was boiled into a gill, and ſet by again. After ſtanding twelve days, I looked to it, and found it gellied. This was evaporated, and gave me 10 dr. of a brown ſalt, that had a ſtrong alkaline cauſtic taſte. By another experiment, in which the ſalts were ſeparated by cold water, I got a ſmall quantity of a neutral ſalt, like the vitriolated tartar, from theſe aſhes.

Exp. 40. The alkaline ſalt, tried with the acid mixture, efferveſced, and conſumed four and a half tea-ſpoonfuls of it. Thus we find the antacid power of the ſalt is much weaker, than that of the aſhes.

I had two reſiduums, one left in the pot, and another in the brown paper, of a blackiſh colour; both which weighed 5 oz. 7 dr. The loſs in boiling, then, amounts to 7 dr.

Exp. 41. On 1 dr. of the reſiduum powdered I poured the acid mixture. An efferveſcence aroſe; the whole turned very black, ſent up a ſtrong ſulphureous ſmell, and tinged the piece of ſilver black. Twenty tea-ſpoonfuls of the acid were conſumed. After the ſaturation there was ſome of the earthy part of the reſiduum at bottom; above it lay a black ſtuff like tar; then the liquor, which was now pellucid, though it was not ſo all the time of efferveſcence. A black ſcum remained on the top till next morning, which then fell to the bottom on ſtirring. What remained in the paper, when the liquor was ſtrained, weighed half a drachm. The liquor being almoſt evaporated was ſet to cryſtallize.

After ſtanding ſome time it was gellied. Being evaporated over a ſlow fire, it gave me 44 gr. of a pale-red ſaline ſubſtance, but no cryſtals.

This ſaline ſubſtance attracted the moiſture ſo ſtrongly, that it could hardly be dried, unleſs put in a ſtrong heat; and, when taken from the fire, turned immediately wet again. It ſeemed to agree pretty much with the ſaline ſubſtance that I ſpoke of before, compoſed of lime and ſpirit of nitre.

Exp. 42. Some Caſhub aſhes powdered, and often waſhed with water, ſo that the ſalts were all carried off, were infuſed in water. After ſtanding ſome time, I had a weak lime-water, that had ſtill ſomewhat of a ſaline taſte, and had no pellicle.

Exp. 43. Some of the reſiduum was put into a reverberatory furnace for two hours. After that it afforded me a good lime-water. Caſhub aſhes, then, appear to contain an earth half vitrified, ſome lime, alkaline ſalts, and a ſulphureous, inflammable, volatile ſubſtance.

Let us inquire whence ariſes the ſulphur of theſe aſhes, of what ſort it is, and what are its effects. Sulphur is a compoſition of the acid of vitriol, and an oil. Any kind of oil will ſerve, whether vegetable or mineral, and make no difference in the compoſition; but no acid will do except that of vitriol. The acid of moſt trees ſeems to be of the vitriolic kind. When they are burnt, the fire diſpels all the watery parts, with ſome of the acid, and the more volatile oils; while the remaining acid, more concentrated by loſing the watery particles, unites with the heavy oils, and ſo forms a ſulphur; which remains in the aſhes, if the fire is not ſufficiently ſtrong, or not continued long enough to conſume it; for all charcoal, if fuſed with alkaline ſalts, diſcovers a ſulphur. It is remarkble, that charcoal does not tinge ſilver when rubbed on it, nor ſhows any other of the effects of ſulphur, until it has been opened by an alkaline ſalt. All theſe materials are found in the Caſhub aſhes; and therefore no wonder that they contain a ſulphur.

But does this vegetable appear to be the ſame with common mineral ſulphur?

Homberg has given us a diviſion of ſulphurs into the vegetable, the animal, the bituminous, and the mineral; and has miſled many by it. That Homberg means the inflammable principle by the word ſulphur, appears from theſe words. L'huile de la plant, qui eſt leur matiere ſulfureuſe *.—He was to blame, as well as moſt of the chymiſts have been, for the vague uſe of that word. That diviſion, therefore, cannot affect the preſent queſtion.

It is plain that common ſulphur may be made as well with a vegetable as with a foſſil oil. The acid of vegetables ſeems to be of the ſame nature as that of vitriol; for with the acid of ſome vegetables and the ſalt of tartar, a tartarus vitriolatus ariſes; and with iron or copper, a vitriol of theſe metals. The acid of many plants ſeems to differ from that of vitriol, only becauſe the former is weaker than the latter. It would appear, therefore, that vegetable ſulphur would no wiſe differ from the mineral but in being weaker.

The effect of this ſubſtance upon cloth is to diſcolour it; as every bleacher knows, if he uſes a lye

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* Mem. de l' acad. des ſcienc. 1702.

a lye of kelp aſhes, or any other ſort of aſhes much impregnated with ſulphur, when the cloth has attained a conſiderable degree of whiteneſs. Let none, however, imagine, that this ſulphureous ſubſtance tinges linen, as much as it does ſilver. This is an effect peculiar to that metal. Sulphur, when mixed with alkaline ſalts, is ſoluble in water, and may in that ſtate be taken out of the cloth by mill-waſhing. But if the alkaline ſalts are ſeparated from the ſulphur, by their ſtronger tendency to ſolution, by their tranſmutation into an abſorbent earth, by meeting with an acid in the water thrown on them, or in the operation of ſouring, the ſulphureous matter, freed from its alkaline diſſolvent, will be precipitated on the ſurface of the cloth; nor will water have the leaſt effect in removing it. A pure lye would again diſſolve this ſulphur; but the continuation of an impure one muſt increaſe its quantity. Hence the neceſſity of a greater evaporation, and longer expoſition to the ſun and winds; the only method left, during the uſe of a foul lye, to carry off theſe colouring ſulphureous particles.

SECT. V.

Marcoft aſhes.

THE Marcoft aſhes are of a paler colour than the former, and have ſome ſmall pieces of charcoal in their compoſition. They have a ſtrong ſaline taſte, with ſo great pungency, that they cannot be held long in the mouth.

Exp. 44. The acid mixture kept up a long fermentation, but not a violent one. A dark-coloured ſubſtance roſe to the ſurface, and likewiſe lay at the bottom on the ſurface of the aſhes. A ſtrong ſulphureous ſmell aroſe; and after ſaturation, which was performed by 13 tea-ſpoonfuls, the liquor had a ſulphureous taſte.

Exp. 45. Half a pound was boiled as the former, and during the ſame time. The decoction was not ſo black as the Caſhub, and had not the ſulphureous ſmell. I forgot to try it when turbid; but the ſtrained decoction, having ſome of the reſiduum left in the paper mixed with it, had no effect on ſilver.

One ounce, therefore, of Marcoft aſhes was boiled in a pint of water to half the quantity. The decoction coloured ſilver very ſuddenly; and when ſaturated with the ſpirit of nitre, let fall a great deal of ſediment. When diluted with 96 waters, it juſt tinctured ſilver. So that the Marcoft ſeems to contain about the half of the ſulphur that the Caſhub aſhes do.

The former decoction boiled into two gills, did not tincture ſilver. It appears by theſe experiments, that the ſulphur in this ſalt is much more volatile than the former, and that the whole of it, by continued boiling, may be diſſipated. On this account it ſeems fitter for bleaching. The decoction having ſtood ſome days, and giving no ſign of any other ſalt, was boiled into a gill. This ſet by for twelve days, turned into a gelly. When entirely evaporated, I had of a ſaline ſubſtance 11 dr. 1 ſcrup. and 2 gr. which added to 5½ oz. of reſiduum, ſhowed the loſs to be 1 oz. 38 gr. By another experiment, in which the ſalts were ſeparated by an infuſion of cold water, I got a ſmall quantity of a neutral ſalt, like the tartarus vitriolatus.

Ex. 46. This ſalt procured by the former experiment, taſtes ſtrongly alkaline; and a half-drachm took 4 tea-ſpoonfuls of the ſaline mixture to ſaturate it. During the efferveſcence I thought I felt a ſulphureous ſmell.

The reſiduum was much of the ſame colour with the aſhes; and is quite inſipid and undiſſolvable in the mouth.

Exp. 47. On 1 dr. of it I poured the acid mixture, which raiſed an efferveſcence much greater than the reſiduum of the Caſhub; but did not turn black, nor ſend up a ſulphureous ſmell, nor tinge ſilver. It conſumed 26 ſpoonfuls. After ſaturation, there was a black tar-like ſubſtance reſting on the remaining powder. The liquor, being ſtrained, left 7 gr. of reſiduum. When evaporated, I had 1 dr. 9 gr. of a ſaline ſubſtance, that would not cryſtallize, had a greeniſh yellow colour, and attracted the moiſture ſtrongly from the air. The antacid quality, therefore, of the earthy part, is to the ſame quality of the ſaline part, as 3¼ to 1.

Exp. 48. To diſcover whether the reſiduum was a calcarious earth, a half-ounce was put for an hour and a half in a reverberatory furnace, during which time it loſt 1 dr. and 1 ſcrup. When put into water, it did not hiſs when mixed; yet next morning I had a ſtrong lime-water with a pellicle, from it.

Exp. 49. To try if I could diſcover any lime in the aſhes themſelves, without the aſſiſtance of fire, I waſhed the ſalts well out with water, after which they afforded me a weak lime-water.

This ſalt, therefore, ſeems to contain the ſame principles with the former; only the ſulphur is in leſs quantity, and more volatile.

It is proper here to inquire, whether alkaline ſalts produced from different bodies, differ from one another? In examining this fact, chymiſts generally ſtate the queſtion thus: "Have alkaline ſalts any ſpecific difference?" Almoſt all of them determine in the negative." Stahl ſays, Fund. Chym. p. 85. Nitrum itaque plantarum, cum generali illa oleoſitate craſſâ ſeu reſinâ, conflagrando, in omnibus vegetabilibus, quæ alkali fundunt, unius generis alkali conſtituit. They allow, that one ſalt is more cauſtic than another, that one is more pure than another; but this, ſay they, is owing to the accidental management of the fire, or the accidental mixture of other bodies. They all allow, that ſalts extracted with tepid water, are not ſo impure, as thoſe with boiling water. The quicker or ſlower evaporation is obſerved to make a difference. But theſe cauſes are ſtill accidental. The ſoda Hiſpanica is obſerved to make finer glaſs, than the much purer ſalt of tartar. But this is owing to a mixture of ſea ſalt with the Spaniſh kelp aſhes, and a mixture of inflammable matter with the ſalt of tartar. Many other differences are obſerved betwixt the different alkaline ſalts; but theſe, they ſay, are owing to accidental, and not ſpecific qualities.

Let us underſtand the terms of the queſtion aright, before we argue on it. The queſtion is thus ſtated by Stahl. An ut plantæ, ita etiam earum ſalia fixa, ſpecie et ſpecifico effectu differunt *? If he means to inquire, whether theſe ſalts have the ſpecific qualities of the plants from which they are got? the queſtion will ſoon be determined in the negative. For the ſalt of poppy enjoys no narcotic quality, nor the ſalt of ipecacuahn an emetic, nor the ſalt of jallap a purgative, nor the ſalt of hemloc a poiſonous. But if he means that one kind of alkaline ſalts have no ſpecific qualities, whereby they differ from another kind, and which the latter, treated the ſame way, may not acquire; and this, by the quotation preceding the laſt, ſeems to be his opinion; I muſt, determined by a variety of experiments made by others, diſſent from ſuch a great chymiſt, and aſſert, that "alkaline "ſalts have a ſpecific difference." Experiment alone can determine this point, and to experiment I ſhall refer the deciſion.

The alkaline baſe of ſea ſalt is found to enjoy ſome particular properties, which no other alkaline ſalt has. It cryſtalliſes like the neutral ſalts. It does not turn moiſt in the air; but, on the contrary, loſes that water which cryſtalliſed along with it, and, of courſe, its tranſparency. When it is combined, and ſaturated with the vitriolic acid, it forms Glauber's ſalt; a ſalt differing in the figure of its cryſtals, its eaſy ſolution in water, and fuſion in the fire, from vitriolated tartar, or a ſalt made of the ſame ſpirit of vitriol and the ſalt of tartar. When it is ſaturated with the ſpirit of nitre, there

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* Fundam. Chym. p. 85.

there ariſes a neutral ſalt, differing from nitre, as it powerfully attracts humidity; and its cryſtals are of a quadrangular figure.

Hoffman, in his 29th obſervation, has ſhown us how differently experiments ſucceed with different alkaline ſalts. The alkaline ſalt of nitre prepared with charcoal, exhaled the ſmell of aqua fortis on an effuſion of ſpirit of vitriol; which ſalt of tartar, or potaſhes, do not; owing perhaps to ſome of the ſpirit of nitre that is not diſpelled by the deflagration. If powder of charcoal is added to ſalt of nitre, or potaſhes in fuſion, a ſort of hepar ſulphuris is formed; but this does not ſucceed with the alkaline ſalts made of nitre and charcoal, or nitre and the regulus of antimony. Salt of tartar, made with or without nitre, differs from the lixivial ſalts; for, on an effuſion of oil of vitriol, a fœtid ſmell ariſes, a black ſcum gathers on the top, and the whole mixture at laſt gains the ſame colour. The ſalt made of two parts nitre and one of the regulus of antimony, affords a red tincture with ſpirit of wine; which a ſalt formed of two parts of nitre and one of tartar, or the common potaſhes, do not. Theſe ſpecific differences in the ſalts of the two laſt experiments, ſeem to be owing to ſome of the oily or ſulphureous particles, which ſtill lurk in them, notwithſtanding all the fire they have ſuſtained.

It appears, then, from theſe experiments, that alkaline ſalts prepared in the common way, from different ſubſtances, are ſpecifically different; and probably have different effects when taken into the human body; but theſe effects are ſo gentle, and ſo maſtered by the alkaline property common to all, that they paſs unobſerved. The fire at length ſeems to diſſipate theſe ſpecific properties, and to reduce the different alkaline ſalts, freed from heterogeneous particles, to one ſimilar nature. The purer theſe ſalts are, ſo much the fitter are they for the uſes of bleaching. The effects of the ſulphur in the Caſhub and Marcoſt aſhes, have already been explained. The great quantity of ſea ſalt which is in kelp aſhes, may render them unfit for bleaching. But this ſtill ſtands in need of farther proof. I do not think that any other ſmall differences betwixt theſe alkaline ſalts can affect their operation on cloth; becauſe that depends entirely on their alkaline property, which can only differ in degree.

SECT. VI.

Method of manufacturing theſe aſhes at home.

ALL reaſoning and experiment ought to be connected with the affairs of mankind; and the cloſer the connection is, the more valuable theſe efforts of the human mind become. It is by this conſideration alone their value ought, and will be meaſured. But what can touch us more nearly than the improvement of our manufactures, on which the riches of our country, and the daily bread of the greateſt number of its inhabitants depend? With this view, then, I ſhall endeavour to make the foregoing experiments more uſeful, and adapt them to the advancement of bleaching, by diſcovering how we may make theſe aſhes, at a much cheaper rate, amongſt ourſelves, while we employ our own hands, and thereby ſave the nation much money. By ſhewing how theſe aſhes may be compounded, we ſhall be able to give the preceding concluſions their full conviction.

The blue and white pearl aſhes we have diſcovered to be pure alkaline ſalts, without any conſiderable mixture of heterogeneous bodies. Their purity ſhews the lixive to have been ſtrained through ſome cloſe ſubſtance, ſuch as linen, or flannel. The blue aſhes ſhew, by their colour, that they have ſuſtained the moſt fire. But both of them are ſo much alike, that the one may be ſubſtituted for the other; and therefore we ſhall conſider them in one view.

Every one knows, that alkaline ſalts, ſuch as theſe, are got from all plants except the alkaleſcent, and from all trees except the moſt reſinous, which afford them in very ſmall quantity. Theſe plants, or trees, when found, are pulled or felled in the ſpring, dried, and burnt to aſhes. By the effuſion of warm water the ſalts are diſſolved, and, by ſtraining, ſeparated from the earth along with the water. This ſaline liquor, which is called a lixive, is evaporated over a fire; and what remains, is an alkaline ſalt of the ſame kind with the pearl aſhes.

I was informed by a ſkilful bleacher in Ireland, that he practiſed a more expeditious way of extracting the ſalts. He bought the aſhes of different vegetables from the commonalty for 9 s. a-buſhel. From theſe a very ſtrong lye was made, into which dry ſtraw was dipped, until it ſucked up all the lye. This ſtraw was afterwards dried and burnt, and gave him ſalts which he ſhewed me, almoſt as good and pure as the pearl aſhes. This method I have ſeveral times tried; but could never burn the ſtraw to white aſhes, the ſalts diminiſhing the inflammability of the ſtraw. It is a very expeditious method, if it can be practiſed. But I can ſee no occaſion for bringing the lye into a ſolid form, as the ſalts muſt again be diſſolved in water before they can be uſed. The ſtrength of the lye can eaſily be determined by the hydroſtatical balance.

Though I make no queſtion, that the quantity of ſalt, in plants of the ſame ſpecies, will vary in different ſoils and climates; yet it would be of advantage to have the proportion aſcertained in general. Some trials of this kind I have made.

Exp. 50. Two pounds of fern which had been pulled Auguſt 16. were dried, and burnt to white aſhes. Theſe weighed 7 dr. and taſted very ſalt. When lixiviated, ſtrained, and evaporated, they gave me 49 gr. of ſalt, about the eighth part of the aſhes. If the fern had been pulled in April, it would have afforded more ſalt. Why then ſhould we not prepare ſalts from this vegetable? There is more of it growing on our hills, than would ſerve all our bleach-fields. The Iriſh make great uſe of it.

Exp. 51. From 11 oz. of tobacco aſhes I had 1 oz. of ſalt. Two oz. of peat aſhes afforded half a drachm of ſalt. Nettles, I am informed, afford much ſalt. Furz and broom, natives of this country, are very fit for this purpoſe.

But the kelp, as it grows in ſuch plenty along our ſhore, and contains more ſalts than any other vegetable I know, would be the moſt proper, were it not for a mixture of ſome ſubſtance that renders it unfit for bleaching, at leaſt of fine cloths, after they have attained a tolerable degree of whiteneſs. It is obſerved by bleachers, that, in theſe circumſtances, it leaves a great yellowneſs in the linen. As theſe aſhes are much uſed in Ireland, and as it is not uncommon to bleach coarſe cloths with them in Scotland, a diſquiſition into their nature, and ſome attempts to purify them, may not be improper. There are no aſhes ſold ſo cheap as theſe; for the beſt gives but 2 l. the 2000 weight. They may, therefore, allow of more money to be expended on them, and come cheaper at long-run than the foreign ſalts.

Exp. 52. I dried ſome ſea-ware, and burned it, though I found that laſt operation very difficult. When I had kept them fuſed in the fire for two hours, they weighed 3 ½ oz. I poured on the aſhes an Engliſh pint and a half of cold water, that I might have as little of the ſulphur as poſſible. This lye, after it had ſtood for ſome hours, was poured off clear, and had but a ſlight tendency to a green colour. I made a ſecond infuſion with milk-warm water, and poured it off from the ſediment. This had a darker colour than the former, was ſeparated from the former, and evaporated by itſelf. There was a third infuſion made; but having no ſalt taſte, it was thrown away. The ſecond infuſion ſeemed to contain more ſulphur than the firſt; and a piece of white linen kept in it half an hour, while it was boiling, was tinged yellow, and could not be waſhed white again. The earthy part remaining weighed, when well dried, 1 oz. 2 dr. The ſaline decoction, evaporated by degrees, and ſet at different times in a cellar to cryſtallize, afforded me 5 dr. 46 gr. The liquor, when entirely evaporated, left 4 ½ dr. of a yellow ſalt, which appeared to be a ſtrong alkaline. The ſalts which cryſtallized ſeemed to be moſtly ſea ſalt, with a conſiderable quantity of ſulphur, and ſome alkaline ſalt. There appeared no ſigns of the bittern in theſe ſalts, as their ſolution did not turn turbid with the oil of tartar. Nor was any of the bittern to be expected in kelp aſhes, although it probably is to be found in the recent vegetable; becauſe the alkaline ſalts formed by the fire, muſt have changed it into a neutral. The lye made with warm water, being evaporated, left 4 dr. of a black bitter ſalt, which, from its quantity of ſulphur, appeared unfit for bleaching. Theſe aſhes, then, ſeem to be a compoſition of ſomewhat leſs than the fourth of ſulphur, the ſame quantity of ſea ſalt, about a fourth of alkaline ſalt, and ſomewhat more than a fourth of earth. The alkaline ſalt contained in kelp aſhes, amounts to one penny a pound. This cheapneſs makes it worth our pains to beſtow ſome labour on them.

If the bad effects of bleaching in kelp aſhes ariſe from the ſea ſalt, as ſome of the moſt knowing bleachers think, they can be freed from it in an eaſy manner. Let a lixive of kelp aſhes be made with cold water, for that does not extract ſo much of the ſulphur; it muſt ſtand but a ſhort time, for theſe ſalts diſſolve eaſily; decant it, and evaporate the lye. As the boiling continues, the ſea ſalt will cryſtallize. When that is all ſeparated, the remaining lye will contain alkaline ſalt with ſome ſulphur. This operation every maſter of a bleach-field may learn and overſee, without taking up much of his time. A ſimilar proceſs is carried on by common ſervants in the allum-works, who have by practice learned it from others.

I had ſome hopes that the ſulphur might be carried off by long roaſting, ſuch as theſe ſalts undergo, before they are fuſed, in order to be turned into glaſs; becauſe I had obſerved, that the longer time they were kept in the fire, the freer they were from this ſulphureous part.

Exp. 53. I ordered a quantity of kelp aſhes to be kept in the furnace of a glaſs-houſe, where the heat was juſt below the vitrifying point, for twenty-four hours. During this time they had loſt almoſt four fifths of their weight. They were now much freer from their ſulphur, and were of a light colour; but much of the alkaline ſalt had been driven off with the oils. If a lye is much impregnated with this ſulphureous matter, it appears to be carried off, in a great meaſure, by boiling.

If we cannot get theſe alkaline ſalts at home in ſufficient quantity, our plantations are ready to afford them, if we are not wanting in induſtry. Our colonies would gain health and riches by the traffic, and we ſhould be provided more certainly, and at a much cheaper rate. The hiccery wood, we are told, affords great plenty of this ſalt. The only way to ſet on foot ſuch a trade as this, would be to ſend from this people ſkilled in the manufacture, with ſuch proper encouragement, for a certain number of years, as the wiſdom of parliament ſhall think fit.

We come now to explain the method of manufacturing the white Muſcovy aſhes. We have ſhewn, by undoubted experiments, that the greateſt part of theſe aſhes conſiſts of lime; and yet we have ſeveral acts of parliament which forbid the uſe of that material under ſevere penalties. The parliament were in the right to diſcharge its uſe, upon the diſadvantageous reports which were made to them. We ſhall immediately ſee, how dangerous a material it is, when uſed improperly, or without the mixture of alkaline ſalts, which render it ſafe, and more ſoluble in water. But I'll venture to ſay, that experiment will not ſupport the prejudice entertained with regard to it, if carried any farther.

Since bleaching, then, cannot be carried on without it; for thoſe aſhes which contain it, are quite neceſſary in that operation; and ſince we import them from foreign countries; let theſe prejudices againſt it ceaſe; and let us only conſider how we may render our own lime as ſafe as the foreign. If we can do that, the wiſdom of the legiſlature will be as ready to abrogate theſe acts, as they were to make them.

By my experiments on the white Muſcovy aſhes, I got about the eighth part of alkaline ſalts from them. This made me expect, that, by mixing in the ſame proportion quick-lime and alkaline ſalts, I ſhould be able to produce Muſcovy aſhes.

Exp. 54. To an ounce of quick-lime and a drachm of pearl aſhes, I added about a gill of water, and boiled them together till the water was all evaporated. The taſte of this ſubſtance was little different from lime. To recover the ſalts again from the lime, I diſſolved it in water, ſtrained off the liquor, and evaporated it. Inſtead of the drachm of ſalts, I had but 2 gr. of a ſubſtance which was more earthy than ſaline.

Exp. 55. To 3 dr. of quick-lime, and as much pot aſhes, I added a mutchkin of water, and kept it boiling for two hours, till it was evaporated. I diſſolved it again in water, which being filtered and evaporated, gave me 1 ½ dr. of a cauſtic ſalt, that liquefied in the air, when it had been but four minutes from the fire. It appears, then, that the alkaline ſalts are deſtroyed by lime, and that a great part of them can never again be recovered. They muſt be reduced to an unſoluble ſubſtance. From the remaining lime, after the ſalts were extracted, I got ſtrong lime-water, but without a pellicle. This ſhews, that a quantity of alkaline ſalts, equal to the lime, boiled with it for two hours, are not able to fix all the ſoluble part of the lime.

From theſe experiments we may draw ſome corollaries with regard to the preſent ſubject. 1ſt, That evaporating the water from the lime and ſalts by boiling, is a moſt unfrugal way of preparing theſe white aſhes. 2dly, That theſe aſhes ought to be kept cloſe ſhut up in caſks; for if expoſed to the open air, though in a room, the alternate moiſture and drought muſt fix their moſt uſeful parts. This I have found to be fact; for the ſalts that I made, became leſs pungent by keeping; and I have obſerved, that the Muſcovy aſhes loſt all pungency, by being expoſed to the air, while their internal parts ſtill retained it. 3dly, That all boiling is prejudicial to theſe Muſcovy aſhes, as it fixes, and that quickly, their moſt ſubtil, and probably their moſt ſerviceable parts.

Let us now proceed to another method of making theſe white aſhes. I imagined, that if the ſalts were diſſolved in water, and the quick-lime ſlaked with that, the maſs would ſoon dry without the aſſiſtance of fire. In this way I added equal parts of both; but the compoſition was ſo ſtrong, that it bliſtered my tongue, if it but touched it. When the fourth part was alkaline ſalt, it bliſtered my tongue, when kept to it a few ſeconds. I could taſte the ſalts plainly in the compoſition, when they made but the thirty-ſecond part of the whole.

I thought, when compoſed with the eighteenth part of ſalt, it had, when freſh made, juſt the taſte and look of the Muſcovy aſhes; nor could any perſon have diſtinguiſhed them. This I once imagined was the proportion; but when I found that the ſaline pungency ſoon turned weaker by keeping, and that this compoſition would not afford the ſame quantity of ſalts that the Muſcovy aſhes did, I ſaw that a much greater quantity of ſalts was neceſſary. The proportion appears to be one of ſalt to four of lime, prepared in the laſt way. Three drachms of aſhes prepared in this way, and kept for a fortnight, gave me but 15 grains of ſalt; which is but the half of what the Muſcovy would have afforded. I find, if the quick-lime is firſt quenched, it does not fix the ſalts ſo much; and therefore is better, and cheaper. One drachm of potaſhes diſſolved in a little water, and added to 3 drachms of quenched lime, gave me 44 grains of a very cauſtic ſalt. I prefer this method as the beſt.

The manufacturers of this ſalt probably pour the lixive upon the lime, as they can know by its ſpecific gravity what quantity of ſalts is in the water, and to ſave themſelves the expence of procuring the ſalts in a dry form.

There is now only one proof wanting to ſhew that theſe are as good as the foreign Muſcovy aſhes, viz. their anſwering as well in the bleach-field. I ſent ſome that I had made to Mr. John Chryſtie, and had the following account of their effects in the bleach-field. "The ſmall parcel "of aſhes which I got from thee, appear to be "very good, and in all reſpects anſwer the pur-"poſes of the Muſcovy white or blanch aſhes. "They are juſt what goes by the name of Riga "Muſcovy blue aſhes; which are the beſt of that "kind. I am ſo well ſatisfied of their anſwering, "that if thou can furniſh me with a parcel next "ſeaſon, I ſhall take them; and doubt not of "bleaching my cloth as well with them, as "with thoſe brought from abroad."

The manufacture of the Marcoft and Caſhub aſhes remains yet to be explained. We have diſcovered, that both of them contain ſulphur, earth, alkaline ſalts, and lime; and differ in nothing, but in the Caſhub's having more ſulphur than the Marcoft aſhes. We ſhall therefore conſider them together.

Whether theſe two ſpecies of aſhes are of any uſe in bleaching, may, and has already been diſputed. I find they contain no other principles, the ſulphureous part excepted, than the former aſhes combined together. Why then ſhould we expect any other effects from the ſame ingredients in the Marcoft and Caſhub aſhes, than what we have from either of the pearl and Muſcovy aſhes mixed together? The ſulphureous principle in the former muſt have very bad effects; as I find by experiment, that it leaves a yellowneſs on cloth, that is very hard to be waſhed out. It is owing to this ſulphureous principle, that linen, after it has been waſhed with ſoap, and is pretty well advanced in whiteneſs, is apt to be diſcoloured by lye if brought to boil: for by boiling the ſulphureous part is extracted from theſe aſhes, and the lye becomes of a deep brown colour. Daily practice, then, ſhews the diſadvantage of this ſulphureous principle. Beſides, as ſulphur unites itſelf, quickly and firmly, with alkaline ſalts, it muſt weaken, or altogether deſtroy a great quantity of theſe in the Marcoſt and Caſhub aſhes, and ſo render them of no effect in bleaching. Theſe two reaſons ſeem to me ſufficient to exclude them from the bleach-field; eſpecially as, by increaſing the other materials, we can attain, perhaps more ſpeedily, the ſame end.

However, as cuſtom has introduced them into general practice, we ſhall conſider how they are to be manufactured. Dr. Mitchell has, in a very ingenious and uſeful paper, contained in the Philoſophical Tranſactions for the year 1748, delivered an account tranſmitted to him by Dr. Linnæus, of the method of making potaſhes in Sweden. This account was contained in an academical diſſertation of one Lundmark upon this ſubject at Aboe in Sweden. The ſubſtance of this account is, " That birch or alder is burnt
" by a ſlow fire to aſhes, and made into a paſte
" with water. This paſte is plaiſtered over a
" row of green pine or fir logs. Above that is
" laid, tranſverſely, another row of the ſame;
" and

“ and that likewiſe is plaiſtered over. In this
“ way they continue building and plaiſtering, ’till
“ the pile be of a conſiderable height. This
“ pile is ſet on fire, and whenever the aſhes begin
“ to run, it is overturned, and the melted aſhes
“ are beat with flexible ſticks, ſo that the aſhes
“ incruſt the logs of wood, and become as hard
“ as a ſtone.” This, in the Doctor’s opinion, is the method of making the potaſhes that come from Sweden, Ruſſia, and Dantzick: and that there is no other difference betwixt the aſhes made in thoſe different countries, but that the Ruſſian, containing more ſalt, muſt be made into a paſte with a ſtrong lye.

There would appear, by my experiments, a greater difference than this, betwixt the Swediſh aſhes, if that is the true proceſs, and thoſe I have examined. I had diſcovered the greateſt part of the Muſcovy aſhes to be lime. I ſuſpected it might enter into the compoſition of the Marcoft and Caſhub; and have accordingly diſcovered it there. Without the ſame grounds, none would ever have ſearched for it. Whence then comes this lime? It muſt either enter into its compoſition, or ariſe from the materials managed according as the proceſs directs. Let us examine this queſtion thoroughly, as it is a queſtion of great moment, and nearly concerns the manufacture of theſe ſalts.

There are two paſſages in chymical authors, that would induce one to believe a very cauſtic ſubſtance might ariſe from the terreſtrial part of vegetables fluxed with the ſaline. Thus Junker,
“ Cineres ligni bitulini recentes, et per cribrum
“ trajecti, ſi aquâ humectantur, et globi, inſtar

"pomorum, exinde conficiantur, dum æſtu in-
"tenſiore globi exſiccantur, poſtea igne ejuſdem
"ligni flammante candefiunt, denique adhuc ca-
"lidi aquâ pura coquuntur; lixivium filtratum,
"et ad conſiſtentiam ſaturati lixivii evaporatum,
"adeo acre redditur, ut lanam injectam in mu-
"cum reſolvet; ſulphur quoque brevi ſolvere
"ſoleat, licet in frigidum lixivium conjiciatur."
The other quotation is from Stahl. "Cauſti-
"cum fit alkali maritatum cum terrâ ſua propria,
"cinere pingui, ſi cineres ex lignis nitroſis, e. g.
"bitulino leviter humectati, denuo urantur
"flammeo igni, ſal deinde mox elixetur et co-
"aguletur*." Both theſe chymiſts, I believe, have formed this opinion, on diſcovering the cauſtic effects of theſe German aſhes; but have taken the proceſs of making them on the faith of others. There is no other perſon who has dealt in chymical operations, but muſt have found the effect of his experiments very different from what the chymiſts made him expect. I have often been deceived; and therefore ſuſpend my belief till my own experience can determine my opinion. I have tried the birch aſhes made into a paſte with water. I have tried common charcoal, made into a paſte with a third part of potaſhes, and kept them in a ſtrong reverberatory heat for ſome hours, and yet no ſuch cauſtic ſubſtance appeared. I have kept the earth and ſalts of kelp aſhes fuſed together for twenty-four hours in the furnace of a glaſs-houſe, where the heat was but juſt below the degree of vitrification; and

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* Vid. Stahl. ſpecim. Buchan. p. 11. ſ. 1. m. 1. No. 58.

and yet no remarkable cauſticity appeared, afterwards, in the concreted maſs. But ſuppoſing that there did, will this ever account for the generation of lime? Theſe chymiſts do not aſſert that it is a calcarious cauſticity. The earth of vegetables kept in fuſion with their ſalts, is ſo far from turning into a quick-lime, that the maſs takes the oppoſite courſe, and becomes glaſs. Bodies that, by the laws of nature, are vitreſcible, can never, ſo far as we know, become calcarious. In one or other of theſe two ſubſtances all bodies terminate, that are changeable by fire; and vegetables are of the former kind. Here it may be aſked, Why then, ſince they endure ſuch a fire, are they not vitrified? The objection would be juſt, did they contain nothing elſe but what was found in vegetables. But if we once allow, that lime is one of the materials, the difficulty is eaſily ſolved; for lime, we know, in proportion as it is mixed, hinders the vitrification of all bodies. In effect, the earthy part in theſe aſhes is almoſt vitrified; and I think that I have carried the vitrification yet farther in that part; but I never was able, with the utmoſt heat of a reverberatory furnace, continued for ſix hours, to produce any thing like a thorough vitrification in theſe aſhes. The heat of the fire uſed in the proceſs, would ſeem to be very great; and muſt, if it were not very difficult, reduce them to glaſs. The invitreſcible nature of theſe ſalts, ſo far from being an objection, becomes a ſtrong proof of my opinion.

Theſe ſalts have a remarkable pungency. This we have already ſeen is the natural effect of quicklime on ſalts.

Theſe ſalts are found to be the fitteſt for making ſcap, and to incorporate ſooneſt and beſt with oils. Salts, we know, of themſelves do not readily unite with oil; but when once mixed with quick-lime, they have a greater tendency to union.

Again, I find that theſe aſhes are more eaſily fluxed than charcoal made into a paſte with the third part ſalt, which is much more than theſe aſhes contain. Now, it is obſerved, that quick-lime increaſes the fluxing power of alkaline ſalt; for the common cauſtic made of quick-lime and alkaline ſalt, is ſooner fuſed than the latter alone.

From theſe reaſons, and the experiments that diſcover lime in theſe aſhes, I am led to think, that it is not generated by the proceſs, but mixed with the aſhes when they are made into a paſte. The following experiment is a convincing proof of what I have been endeavouring to make out.

Exp. 56. I boiled ſome peaſe ſtraw in a ſtrong lye of pearl aſhes, burnt into a black coal, and made it into a paſte with water. Another quantity of ſtraw was boiled in a lye made of one part quick-lime, and four parts pearl ſalts, the lye being poured off turbid from the lime. This ſtraw was likewiſe burnt when dry, and made into a paſte. Theſe two ſubſtances were put into ſeparate crucibles, and fluxed in a reverberatory furnace. The latter appeared to reſemble the Marcoft and Caſhub aſhes, more than the former, which ſeemed to want their pungency.

Long after I was ſatisfied this was the way of manufacturing theſe northern aſhes, I accidentally met with an obſervation of a knowing bleacher. Mr Chryſtie ſays, that he was told by Mr Robert Douglas, who had been in Ruſſia, Sweden, and many other parts, that he had ſeen the following method of making aſhes practiſed. "The aſhes of burnt wood "or weeds were mixed with quick-lime, put "into a fat or receiver, and a very ſtrong lye "was drawn from them by water, juſt as "bleachers make their lye. In this lye dried "wood or weeds were ſoaked, until they "would imbibe no more, and then burnt in "ovens prepared for that purpoſe. Theſe "ovens had a ſtrong draught of air, which "made the fire burn moſt furiouſly; and as "the wood was fluxed in the fire, it fell "through the grate, and run into hard "lumps." Theſe aſhes, by this deſcription, appear to be Caſhub, or Marcoft aſhes, I would recommend this method as the eaſieſt and quickeſt of manufacturing theſe ſalts at home.

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PART IV.

SECT. I.

The natural effects of theſe aſhes, and other bodies, on unbleached cloth.

IT is no wonder, that the art of bleaching has, as yet, made ſuch ſmall advances, when the facts and circumſtances are confined to the bleachers alone, and the natural effects of different bodies on cloth are, even to them, unknown. There are two cauſes, among many, to which the latter ought principally to be attributed. The generality of thoſe who practiſe bleaching, look on it as a buſineſs already brought to perfection; and, being ignorant of natural philoſophy, and the experimental method of carrying it on, never imagine the further progreſs which it could beſtow on this art. The other cauſe which retards the progreſs of bleaching, is a want of accurate obſervations on the effects of the different agents which are employed in it. And, indeed, it is impoſſible that theſe obſervations ſhould be made in the common courſe of buſineſs, conſidering how theſe aſhes are mixt together, when uſed by bleachers, ſo that the particular effects of each can never be known; and conſidering how the other operations of this proceſs immediately ſucceed thoſe applications, by which the effects of all are blended together.

To remedy a defect which cannot well be obviated in the bleachfield, I have made a few experiments, in order to diſcover the effects of different ſubſtances on unbleached cloth. As this is but an attempt towards a complete ſet of experiments in bleaching, I hope they will excite others, whoſe proper buſineſs it is, and who have greater opportunities than I of purſuing the like reſearches. They will point out the general method to be followed in making ſuch experiments. However diſagreeable or tedious the plain narration of experiments may appear, there is no other way to arrive at truth; eſpecially in an art where, from a deficiency in theſe, there is as yet, but little certainty.

That I may make theſe experiments as accurate and extenſive as poſſible, I ſhall try them with different degrees of heat; with that of the atmoſphere, with a gentle degree of heat equal to that of the human body, and with the heat of boiling water; for the effects of moſt diſſolvents are increaſed by the heat. The cloth uſed in the following experiments, was ſteeped in warm water for a night to take out the dirt and dreſſing.

Exp. 57. July 26. To diſcover the effects of pearl aſhes, I diſſolved 10 gr. of pearl aſhes in 6 oz. of water, and put a piece of unbleached cloth, about 15 ſquare inches, into the ſolution. After it had been in this weak lixive about a minute, a great many air-bubbles aroſe to the ſurface. 28. Ten grains more of the ſalts were added, and more air-bubbles aroſe as before. The lixive had now a ſtrong alkaline taſte. Aug. 7. The lixive taſtes much weaker. The cloth appears to have a redder caſt than a piece of the ſame cloth in plain water.

Thirty grains more of the ſalts were added. About half an hour afterwards a great many air-bubbles were on the ſurface of the liquor, and many more aroſe on touching the glaſs. 9. I immerſed the glaſs half-way up in warm water, and kept it there for two hours and a half, renewing the warm water. During that time I ſaw no air-bubbles ariſe. 26. The water had no alkaline taſte, and the cloth had a deep red colour. 28. That I might ſee the natural colour of the cloth, and diſcover its degree of firmneſs, I took out the alkaline ſalts, by ſteeping the cloth all night in water acidulated with ſpirit of nitre. I could obſerve no fermentation or inteſtine motion in the liquor. The cloth, being waſhed in warm water, and dried at the fire, appeared much whiter than when it was put into the lixive. I ſhall diſtinguiſh the colours in the following experiments, at this particular time, into four different claſſes, according to their different degrees of whiteneſs, placing the whiteſt in the firſt claſs. According to this diſtribution of colours, the cloth in this experiment was in the third claſs; it ſeemed as firm and ſtrong as at firſt. Sept. 9. The cloth was taken out, waſhed with ſoap and water, and dried. There was not ſuch a diſtinction betwixt the colours of the different cloths at this inſpection as there was at the laſt; but ſtill this cloth was inferior in colour to the reſt. 21. There appeared a great ſediment at the bottom of the glaſs. When the cloth was waſhed and dried, it was amongſt the darkeſt-coloured, though whiter than at laſt inſpection. It is ſtill ſtrong. I renewed the water, and added half an ounce of pearl aſhes, to diſcover if theſe ſalts could weaken cloth. Nov. 11. The cloth appears no whiter, and no weaker.

Exp. 58. July 26. To diſcover the effects of Muſcovy aſhes, I added half a drachm of white Muſcovy aſhes in powder, to 6 oz. of water; and infuſed, in this mixture, the ſame quantity of cloth, as in laſt experiment. 28. I added the ſame quantity as before. The cloth juſt begins to whiten. Aug. 9. The glaſs ſtood two hours and an half in warm water. 26. The water had ſcarcely any taſte. 28. The cloth was ſteeped all night, with the former, in water acidulated with ſpirit of nitre. When dried, it appeared to be in the ſame claſs of colours with the former. It was remarkably weaker, ſo that I could eaſily tear it, when I could not the former. Sept. 9. Waſhed with ſoap, and dried, it now appeared to be in the firſt claſs of whiteneſs; ſtill weaker, but not ſo much as the cloth, in ſhell-lime water. 21. Much whiter, but ſcarcely any weaker. Nov. 11. Not ſo white as the cloth in the lime-water, nor ſo weak.

Exp. 59. July 26. To diſcover the effect of Marcoſt aſhes, I boiled a drachm and a half of Marcoſt aſhes for half an hour in 6 oz. of water, adding, at the latter end, as much water as was loſt by evaporation. Boiling is neceſſary to extract the ſalts from theſe aſhes. In this lixive the ſame piece of cloth as in the former, was infuſed. Aug. 7. No whiteneſs yet begins to appear; the cloth ſeems rather ſomewhat reddiſh. 9. When the glaſs was put into milk-warm water, as the former were, air-bubbles aroſe. 28. The cloth was ſteeped all night in water, acidulated with ſpirit of nitre. When dried, it appeared in the third claſs as to whiteneſs; it ſeemed conſiderably weaker. Sept. 9. Whiter and weaker; 21. Very white, but quite rotten. Nov. 11. Scarcely ſo white as the cloth in the two following experiments, but almoſt as rotten. Caſhub ſeems, by experiment, to have much the ſame effect as Marcoſt, in weakening cloth, but leaves a much redder colour on it.

Exp. 60. July 16. To diſcover the effects of lime-water, I infuſed the ſame quantity of the ſame cloth in ſtone-lime water. It ſent up directly a great many more air-bubbles than any of the reſt. Aug. 7. The cloth begins to appear whiter. No ſediment to be ſeen. As the lime-water had almoſt loſt its taſte, all the glaſſes being but ſlightly corked, I renewed the lime-water. 9. The glaſs was put for two hours and a half in milk-warm water, during which a few air-bubbles aroſe. 26. Not much whiter than the laſt time. A brown ſubſtance at the bottom of the glaſs. 28. Steeped the cloth for a night in water acidulated with ſpirit of nitre, to take the particles of lime out of it. When dried, the cloth appeared to be amongſt the whiteſt in the third claſs of colours. I did not yet diſcover it weaker. Renewed the lime-water. Sept. 9. When waſhed with ſoap, and dried, it equalled the cloth that had been ſteeped in the Muſcovy aſhes, and ſurpaſſed all the reſt. It ſeems weaker. 21. It appears now very white, and very tender. Renewed the lime-water. November 11. No whiter, but rather weaker.

Exp. 61. Aug. 10. That I might diſcover what effect oyſter-ſhell lime-water would have on cloth, as it has a ſtronger power in diſſolving the human calculus than ſtone-lime water, I ſteeped the ſame quantity of the ſame cloth in the ſame quantity of ſhell-lime water. 26. Remarkably whiter, even more ſo than the cloth in the ſtone-lime water, that had been ſteeped double the time. 28. To take out the particles of lime, it was infuſed for a night in water, acidulated with ſpirit of nitre. When dried, it appeared rather whiter than the cloth of the former experiment, and as much weakened. Renewed the ſhell-lime water. Sept. 9. When waſhed with ſoap and water, it appeared whiter, but with a yellowiſh caſt. It was much tenderer than the cloth of the former experiment. 21. Exceeding white, though with a yellow caſt, but quite rotten. November 11. No whiter, but very weak.

Exp. 62. July 26. That I might diſcover the effects of alkaline ſalts and lime combined together, I ſlaked half a drachm of quick-lime with an equal quantity of pearl aſhes diſſolved in water. In this mixture an equal quantity of the ſame cloth as in the former experiments, was ſteeped. Some air-bubbles aroſe immediately. Auguſt 1. Some clouds were ſuſpended in the liquor; and a filmy oozy matter was depoſited at the bottom. 7. The cloth appears whiter. The lixive taſtes yet very ſtrong. 9. I added the ſame quantity of lime and ſalts, as the lye was beginning to turn weak. The glaſs was two hours and a half in milk-warm water, during which time many air-bubbles aroſe. 26. The lye taſtes much weaker. 28. Steeped all night in the ſame acidulated water as the former were, and dried. This cloth was now the whiteſt of the whole, though it did not appear ſo before it was ſteeped in the acid. It is therefore to be ranked in the firſt claſs at preſent. Appears to be no weaker. Added to the liquor 5 gr. of the cauſtic ſalt extracted from equal parts of quick-lime and alkaline ſalts, and therefore of the ſame kind with the former. Sept. 9. The cloth waſhed with ſoap, and dried. Whiter than before; yet was ſcarcely ſo white as the cloth in lime-water, or that in the Muſcovy aſhes. 21. The cloth has now attained a very great degree of whiteneſs, and ſeems no weaker than when it was firſt put into the lixive. Nov. 11. As white as the cloth in the lime-water, and as ſtrong as cloth that has been bleached in the ſafeſt way.

Exp. 63. July 26. To diſcover what effects lime-water with a few grains of alkaline ſalt would have on unbleached cloth, as this would be a cheaper method of bleaching than any of the former, I added to 6 oz. of ſtone-lime water, 10 gr. of blue pearl aſhes. When the ſalts were added, the liquor turned white, curdled as hard water does with ſoap, and in a little time a great quantity of white powder was precipitated to the bottom. Into this mixture the ſame quantity of the ſame unbleached cloth was put. 28. The liquor taſted like a weak ſolution of ſoap. Aug. 1. A ſmall quantity of a filmy matter appears ſwimming in the mixture. 7. No whiteneſs yet appears. 9. Was two hours in warm water. 26. Taſtes ſtill pretty ſtrong. 28. Steeped all night in the acidulated water, and dried. Appears now in the ſecond claſs of whiteneſs; and though not ſo white as the cloth in the former experiment, yet ſurpaſſing all the reſt. September 9. The cloth waſhed with ſoap, and dried. Though whiter than before, yet is not ſo white as that in the lime-water, or Muſcovy aſhes. Appears to be no weaker. 21. Is now very white, and a very little weaker. The liquor renewed. Nov. 11. This cloth appears as white as thoſe in the ſtone and oyſter-ſhell lime-waters. It ſeems to be no weaker than cloth that has been bleached in the beſt manner.

Exp. 64. July 26. To diſcover the effects of oil of vitriol, the ſame quantity of the ſame cloth was put into the ſame quantity of water, to which were added 30 drops of the oil of vitriol. 28. Added 30 drops more. The water has a gentle acid taſte. Aug. 1. A white ſediment, or oily-like matter lies at the bottom of the glaſs. 7. The liquor has no acidity. An oozy matter, ſimilar to what was before obſerved at the bottom, is now to be ſeen floating in the liquor, and adhering to the cloth. The colour of the cloth is whiter than a piece of the ſame that had been for the ſame time in water. Sixty drops more were added, and the glaſs is put four hours in milk-water; during which a great many air-bubbles aroſe, and the liquor afterwards taſted much leſs acid. Cloth ſtill firm. Sixty drops more added. 14. Covered all over with the oozy, oily-like matter. 25. Appears whiter, with more of that oozy matter. The liquor is leſs acid. The cloth ſtill ſtrong. Renewed the water, and added 100 drops to it. 28. That I might take the acid ſalts out of the cloth, and diſcover its real colour, I ſteeped this cloth and that of the two following experiments, in a ſo-a ſolution of alkaline ſalts. I obſerved a fermentation, or inteſtine motion, in the liquor. When the cloth was waſhed and dried, it was much behind thoſe in the foregoing experiments in colour, and but juſt a degree whiter than a piece of the ſame cloth that had been in plain water. It looked whiter when in the glaſs. It muſt therefore be placed in the fourth claſs. This cloth, and the two pieces in the following experiments, felt hard and rough. Sept. 9. Waſhed with ſoap and water. It was ſtill much behind the former in colour. As ſtrong as at firſt. Nov. 11. Colour and ſtrength the ſame.

Ezp. 65. July 26. To try the effect of ſpirit of nitre, the ſame quantity of the ſame cloth was ſteeped in the ſame quantity of water, to which were added 30 drops of the ſpirit of nitre. The liquor taſted gently acid. Immediately after the cloth was put in, it was all full of air-bubbles. 28. The air-bubbles ſtill adhering to it. Added 30 drops more. Aug. 1. A white ſediment lying at the bottom. Leſs acid than what it was before, and about the ſame degree with that of the former experiment. A ſmall degree whiter than the cloth in plain water, but not ſo white as the cloth in the vitriol. 8. The glaſs immerſed half-way in milk-warm water for four hours. More air-bubbles ariſe from this glaſs than from any of the others. That part of the cloth that was below the ſurface of the warm water, ſeemed, after the glaſs was removed, to be whiter than that above the ſurface. As the liquor taſted leſs acid, 30 drops were added. The cloth ſtill firm. 26. The liquor more acid than the vitriolated liquor in the foregoing experiment. The cloth as white and as ſtrong, but not ſo much of the oozy matter as in that. Renewed the water with 100 drops of the ſpirit. 28. After being ſteeped all night in the lye with the former, it appeared rough and hard, and of the ſame colour with it. Sept. 9. After being waſhed with ſoap and water, of the ſame colour as the former. As firm as at firſt. Nov. 11. Colour and ſtrength the ſame.

Exp. 66. July 26. To diſcover the effects of the ſpirit of ſea ſalt, the ſame quantity of the ſame cloth was ſteeped in the ſame quantity of water, and 30 drops of the ſpirit of ſea ſalt. The cloth was immediately covered all over with air-bubbles. 28. Liquor ſtill acid. Added 30 drops more. Aug. 1. This liquor is the moſt acid of the three. A white ſediment at the bottom, but not ſo much as any of the former. 7. More acid than the vitriol, but leſs of the oily-like matter ſuſpended in it. Added 30 drops more. A degree whiter than the cloth in plain water, but ſcarcely ſo much as that in the vitriol. 8. The glaſs was four hours in warm water; during which time many air-bubbles aroſe, and afterwards the liquor was leſs acid. That part of the cloth that was in the warm water, and had ſuſtained the greateſt heat, was whiter than the upper part. Cloth firm. Added 30 drops. 26. Not ſo white as the former two. No oozy matter at bottom. The liquor very acid. 28. When treated as the former, was as rough, and ſcarcely ſo white. As the glaſs was broke at this time, I added 60 drops to the ſame quantity of water. Sept. 21. Whiter, but no tenderer. The liquor is ſcarcely acid. Added 100 drops more. Nov. 11. Colour and ſtrength the ſame.

That I might ſee what effects plain water had upon cloth, and, by that, more certainly judge of the real effects of theſe alkaline and acid ſalts.

Exp. 67. July 26. I put the ſame quantity of the ſame cloth in the ſame quantity of plain water. Aug. 1. Water begins to ſmell. A filmy oozy matter at the bottom. 7. Water ſpoiled, ſo renewed. 8. When in the milk-warm water, ſome air-bubbles aroſe, but fewer than in the reſt. 26. Renewed the water. Sept. 9. The cloth had a yellow caſt. 21. A very little whiter, but no tenderer. Nov. 11. Whiter.

To diſcover if ſoap has any power in whitening unbleached cloth more than removing the the dirt on the ſurface.

Exp. 68. Sept. 9. Forty-four grains of the ſame cloth was ſteeped in 8 oz. of water, in which was diſſolved 2 dr. of Caſtile ſoap. Nov. 11. The cloth was of the ſame colour and ſtrength as when put in; and, when waſhed and dried, weighed 45 gr.

That I might diſcover the effect of ſea ſalt on unbleached cloth.

Exp. 69. Aug. 30. I diſſolved half a drachm of pure ſea ſalt without any mixture of the bittern, in 6 oz. of water, and infuſed a piece of cloth in it. Sept. 21. Cloth a degree whiter, but no tenderer. Nov. 11. The cloth appears rather darker than when put in, and is remarkably thinner and weaker. There is much black matter at the bottom of the glaſs. As I imagined that theſe effects proceeded in ſome meaſure from corruption, which is aided by a ſmall quantity of ſea ſalt, I repeated this experiment twice, once with 2 dr. and once with 4 to the ſame quantity of water. After they had ſtood eight weeks, the cloth in each appeared thinner, weaker, and no whiter.

That I might diſcover the effect of putrefaction on cloth.

Exp 70. Aug. 8. A piece of the ſame cloth was put in water. 26. Water much ſpoiled, and the cloth very black. 30. The cloth ſtill blacker, and ſome black matter like ſoot, has fallen to the bottom of the glaſs. There is a pellicle on the ſurface of the liquor. The cloth, when dried, was no weaker. Sept. 9. The water ſtunk abominably, and the cloth as black as ſoot before waſhing, but was not ſenſibly weaker. Sept. 21. Still black, but no weaker. The quantity of black precipitated matter increaſed. Nov. 11. The cloth waſhed with ſoap and dried, appears a very little darker, with ſome yellow clouds in it, and is much weakened.

My next experiments were made with a view to diſcover what effect a gentle degree of heat, equal to that of the human body, would have on the action of theſe bleaching materials.

Exp. 71. Aug. 10. The ſame quantity of the ſame cloth was ſteeped in the ſame quantity of water, in which 40 gr. of white pearl aſhes had been diſſolved, and ſet ſo near the kitchen-fire, as to keep it in the forementioned degree of heat. 14. The cloth was whiter. 28. Steeped all night in the ſame acidulated mixture with the others, and dried it. Appeared much whiter, and was at preſent next to the cloth in the lime and aſhes of thoſe four experiments made with this degree of heat. Sept. 9. Whiter than the following experiment made with the oil of vitriol. 21. Whiter, and ſtill ſtrong. Added 40 gr. more. Nov. 11. No whiter, and no weaker.

Exp. 72. Aug. 10. The ſame quantity of the ſame cloth was infuſed in the ſame quantity of ſtone-lime water, and that the fire might not ſoon evaporate the lime, 2 tea-ſpoonfuls of fine ſlaked lime were added. 14. Begins to whiten. 28. The cloth not ſo white as in the laſt experiment at this time. Sept. 9. This was now the whiteſt of thoſe that ſtood at the fire, and much more ſo than the cloth of any of the experiments made without any heat, but is very tender. 21. The whiteſt of the whole, but ſo tender, that it ſeparated with the leaſt force. Nov. 11. The cloth is now ſo rotten, that it has fallen all to pieces in waſhing it, and can be reduced, betwixt the fingers, to a powder.

Exp. 73. Aug. 10. The ſame quantity of the ſame cloth infuſed in the ſame quantity of water, to which was added 1 dr. of home-manufactured Muſcovy aſhes, viz. 4 parts of quick-lime ſlaked, with 1 part pearl aſhes and water. 14. Begins to whiten. 28. This cloth was now the whiteſt of all thoſe at the fire. Sept. 9. Neither ſo white nor ſo weak as the cloth in the former experiment. 21. Very white and tender. Nov. 11. Quite rotten, though not ſo much as the former.

Exp. 74. Aug. 10. The ſame quantity of the ſame cloth in the ſame quantity of water. to which was added 95 drops of the oil of vitriol. 14. Whiteneſs juſt begins to appear. Added 70 drops more. The leaſt advanced of the whole at the fire in whiteneſs. Sept. 9. It had now a deep reddiſh caſt. 21. Much whiter, but no weaker. Nov. 11. The cloth has got a reddiſh colour, and is no weaker.

Let us now ſee the effect of theſe ſalts when the heat employed ariſes to that of boiling water.

Exp. 75. Sept. 11. Three drachms of unbleached cloth, at 13d. a yard, was put into a pint of water, in which was diſſolved 1 dr. of pearl aſhes, and the water gradually brought to boil. It was kept boiling for five hours, having filled it twice up with water, as the boiling diminiſhed it. When it had boiled two hours, the decoction had no longer any taſte of the ſalts, and was high coloured. When the five hours were elapſed, the cloth was taken out, wrung, and waſhed in warm water. When dried, it was ſtill firm and ſtrong, and weighed 2 dr. 50 gr.: ſo that it had loſt 10 gr. Being expoſed to the influence of the air all night, and next day, which was very hot and clear, and regularly watered as it dried, the cloth loſt 3½ gr. Sept. 13. Boiled as before in a freſh lye, wherein 1 dr. of pearl aſhes was diſſolved. When it had boiled two hours, I added 1 dr. more. Five hours after that 1 dr. more was added. It was removed when it had boiled thirteen hours; at which time the lye taſted ſtrong; waſhed, and dried. The cloth was ſtill firm, had a yellow colour, and weighed 2 dr. 40 gr. So that it had loſt 6½ gr. on this laſt boiling. In order to diſcover what quantity of the ſaline particles remained in the cloth, I ſteeped it in water and vinegar, equal parts, for half an hour. When the cloth was firſt put in, there was a great fermentation, or inteſtine motion, and many air-bubbles aroſe. Waſhed and dried, it was 2 gr. lighter. During the 14th, 15th, and 16th of September, it was expoſed night and day, and watered. Waſhed and dried, the cloth weighed 2 dr. 33 gr. Sept. 17. The ſame cloth was put into the laſt decoction, as it was yet ſtrongly alkaline, to ſee if theſe ſalts could weaken it. Having boiled eleven hours, it was taken out, waſhed and dried, and weighed 2 dr. 38½ gr. So that it had gained 5 gr. So that it had gained 5 gr. from the foul decoction. It was now about the ſtrength of cloth that comes from the bleachfield; and though not tender, yet was weaker than at firſt. To carry off the foulneſs and ſalts that it had abſorbed from the lye, and diſcover its real diminution, I put it in vinegar for three minutes. Air-bubbles aroſe. Waſhed and dried, it weighed 2 dr. 30½ gr. I now diſcovered that the laſt boiling had extracted 2½ gr. from it. Expoſed from twelve to ſeven at night in a ſtrong wind, but no ſunſhine, and watered twice, it weighed 2 dr. 28½ gr. Sept. 20. The cloth was put into butter-milk, that had been well ſkimmed, and ſoured by boiling with a little water, ſo that it was now very thin, and as ſour as good vinegar. Some air-bubbles aroſe. 22. The whey no longer ſour. 24. The cloth taken out, waſhed in warm water, and dried, weighed 2 dr. 33½ gr. ſo that it has gained 5 gr. of additional weight from the butter-milk.

Exp. 76. Sept. 12. Two drachms fifty-two grains of the ſame cloth were boiled as the former, with 1 dr. of Muſcovy aſhes, for five hours. When waſhed and dried, it weighed 2 dr. 46½ gr. The Muſcovy aſhes had been kept by me for four months, and they ſeemed to me not to be very ſtrong. The colour was like the former. Expoſed in a cloudy but warm day, I obſerved, that when dry, it did not imbibe the water that was thrown on it, but allowed the water to run off as if the cloth had been oiled; and when I thought the cloth was ſufficiently wet by watering it, I found the oppoſite ſide almoſt dry. It was expoſed for twenty-four hours. When dried, it weighed 2 dr. 43 gr. The cloth was divided into two different pieces, which weighed 1 dr. 21 gr. each. To try what effect Caſtile ſoap has in the lye, and if it corrects the corroding quality of the Muſcovy aſhes, I put one half which I ſhall call N° 1. into an Engliſh pint of water, to which was added 1 dr. of Muſcovy aſhes; and N° 2 into the ſame, with an addition of half a drachm of Caſtile ſoap. After they had boiled two hours, 1 dr. of Muſcovy aſhes was added to N° 1.; and the ſame, with the addition of half a drachm of Caſtile ſoap, to N° 2. Five hours afterwards the ſame addition was made to each. After they had boiled thirteen hours,

both

both pieces of cloth were taken out, waſhed, and dried. Both pieces were much weakened: if there was any difference betwixt them, N° 2 was moſt ſo. N°. 1. weighed 1 dr. 16 gr.; N° 2. 1 dr. 18 gr. Both pieces expoſed to the air, and watered, for twenty-four hours, then dried, N° 1. weighed 1 dr. 12½ gr.; N° 2. 1 dr. 15 gr. Sept. 16. Put both pieces in a pint of butter-milk. 24. The milk is whigged, and ſtill pretty ſour. Took out both pieces, waſhed and dried them. N° 1. weighed 1 dr. 12½ gr. No. 2. 1 dr. 14 gr.

Exp. 77. Sept. 12. One drachm and a half of the ſame cloth was boiled as the former, with 1 dr. of Marcoft aſhes, for five hours. When waſhed and dried, it weighed 1 dr. 21½ gr. The cloth was whiter, but had a yellow caſt. Sept. 13. Laid out to dry at ten a. m. in a cloudy day. This cloth, when dry, quickly imbibed the water that was thrown on it. This expoſed for twenty-four hours in cloudy weather, ſeemed the whiteſt of all the pieces that were boiled. Taken up Sept. 16. in the evening, it weighed, when well dried, 1 dr. 18 gr. and was ſtill firm and ſtrong. The cloth was ſteeped in an acid liquor, conſiſting of two parts water and one part vinegar. Taken out Sept. 18. waſhed and dried, it weighed 1 dr. 17½ gr. When boiled in half a pint of water, and 2 dr. of Marcoft aſhes, for thirteen hours, waſhed and dried, it weighed 1 dr. 12½ gr. The cloth was as ſtrong as at firſt. Expoſed in ſunſhine, and a good gale of wind, from nine a. m. to ſeven p. m. and watered four times during that time, it weighed 1 dr. 15 gr. The water that I uſed in theſe experiments, was in the ſecond claſs of hardneſs, and might therefore have left ſome particles behind in the cloth, or the wind might have blown ſome duſt upon it. This cloth has now attained a conſiderable degree of whiteneſs, and appears to be a little weaker. Soured in the ſame butter-milk whigged, as is deſcribed in Exp. 75. for four days, then waſhed in warm water and dried, it weighed 1 dr. 13½ gr. It ſeemed now to have again recovered all its ſtrength.

Exp. 78. Sept. 11. Boiled 2½ dr. of the ſame cloth the ſame way as in the former experiments, in an Engliſh pint of water, and 50 gr. of quick-lime. After it had boiled five hours, the decoction taſting ſtrongly of lime-water to the laſt, the cloth, when waſhed and dried, weighed 2 dr. 8 gr. ſo that it had loſt 22 gr. of its weight; and if we allow that ſome of the lime might ſtill be in the cloth, it muſt have loſt more. It was evidently thinner, and ſcarcely ſo white as the cloth boiled the ſame time in the pearl aſhes. Expoſed to the air for twenty-four hours, the day being very clear and very hot, it loſt 1½ gr. Sept. 13. This cloth was boiled for thirteen hours, adding 50 gr. of lime at proper intervals, as in the former caſes. When waſhed and dried, it weighed 2 dr. 5½ gr. Appeared remarkably whiter, weaker, and was full of white duſt, which appeared whenever the cloth was ſhaked or tore. To diſcover what quantity of the lime it contained, it was ſteeped in warm water and vinegar, waſhed and dried: it weighed 2 dr. 1 gr. It ſeemed now conſiderably ſofter, and thinner, and was not eaſily wetted by the water which was thrown on it.

Exp. 79. Sept. 12. To diſcover the effect of pearl aſhes and lime mixed together, 3 dr. of the ſame cloth was boiled in an Engliſh pint of water and pearl aſhes, and quick-lime, half a drachm each, for five hours. The cloth, when waſhed and dried, had a reddiſh colour, and weighed 2 dr. 44 gr. Expoſed directly to the air, watered for four days, and dried, it weighed 2 dr. 36½ gr. No weaker. That I might take all the alkaline particles out of it, the cloth was ſteeped in freſh churned milk and water, equal parts, for forty-eight hours. It weighed, when waſhed and dried, 2 dr. 39 gr. It was boiled for thirteen hours in quick-lime and pearl aſhes, 3 dr. each, adding them at proper intervals, as in the former experiments. The cloth, when waſhed and dried, weighed 2 dr. 18 gr. It ſeemed weakened, but not ſo much as in the laſt experiment. Sept. 20. Steeped in the ſour whig of butter-milk for four days. It weighed, when waſhed and dried, 2 dr. 15½ gr.

To diſcover the effects of pearl aſhes mixed with the Muſcovy aſhes as they are in the bleachfield.

Exp. 80. Sept. 12. I boiled 3 dr. of the ſame cloth in a pint of water, to which were added 40 gr. of Muſcovy and 20 of pearl aſhes, which I computed to be nearly of the ſame ſtrength as equal parts of quick-lime and ſalts. When it had boiled five hours, was waſhed and dried, it weighed 2 dr. 32 gr. Expoſed to the ſun at two p. m. and watered, and taken up Sept. 16. in the evening, it weighed 2 dr. 27½ gr. The water did not penetrate it well. No weaker. To ſee if any alkaline particles yet remained in the cloth, it was ſteeped in water and vinegar. When dried, it weighed 2 dr. 23 gr. Sept. 24. Boiled for twelve hours in 3 dr. of pearl aſhes and as much Muſcovy, adding 1 dr. of each at proper intervals, as in the former experiments; when waſhed and dried, it weighed 2 dr. 39½ gr. The cloth boiled in the quick-lime and pearl aſhes, and that in the Marcoſt aſhes, were the whiteſt of the laſt ſix experiments. The other four pieces were pretty much of the ſame colour. The cloth appeared to be much of the ſame ſtrength as that in the laſt experiment.

To diſcover the effects of the mineral acids with a boiling heat.

Exp. 81. Sept. 18. I boiled 42 gr. of the ſame cloth in a half Engliſh pint of water, to which were added 2 dr. of the ſpirit of vitriol. After it had boiled five hours, the water was ſtill acid. The cloth, when waſhed and dried, weighed 38 gr.

Exp. 82. To try the effect of ſoap, I boiled 39 gr. of the ſame cloth in half a pint of water and 1 dr. of Caſtile ſoap. The water was kept boiling for five hours. The cloth, waſhed and dried, weighed 38½ gr. It had therefore loſt only half a grain during five hours boiling.

To ſee what effect plain boiling water would have on cloth, that I might not attribute what belonged properly to it, to the different bodies, that I have been trying.

Exp. 83. Forty-two grains of the ſame cloth were boiled, as the others had been, for five hours in water. When dried, it weighed 41½ gr. It had got ſomething of a yellow colour; and was evidently weaker; for I tore it, but indeed with ſome difficulty, which I could not do before it was boiled.

Although it is the practice with bleachers to mix ſoap with their lye, yet the necceſſity or utility of it is ſtill a doubtful queſtion. In defence of the common practice, it is ſaid, that the ſoap blunts the ſharpneſs of the ſalts, and makes the lye more ſafe. On the contrary, it is alledged, that making the lye weaker would have the ſame effect, and the ſoap would be ſaved. This queſtion is only to be determined by experiment.

Exp. 84. Sept. 11. Forty-five grains of unbleached cloth were infuſed in a pint of lime-water. Nov. 15. Cloth is much weakened, and weighs 43½gr.

Sep. 11. I put the ſame quantity of cloth in the ſame quantity of lime-water, with the addition of half a drachm of Caſtile ſoap; which broke in it as in hard water. Nov. 15. The ſoap ſtill ſwimming on the top; and the cloth as weak as in the former caſe, but feels ſofter.

Sept. 11. Forty-four grains of the ſame cloth were put into a pint of water, to which were added 2 ſcrup. of Muſcovy aſhes and half a drachm of Caſtile ſoap. In this the ſoap diſſolved tolerably well. Nov. 15. Cloth weaker, and weighs 41 gr.

Sept. 11. Forty-five grains of the ſame cloth were put in the ſame mixture, with the addition of half a drachm of pearl aſhes. Nov. 11. The cloth as white as the former; is not weakened, and weighs 42 gr.

It appears, then, that the corroding power of lime and Muſcovy aſhes is not weakened by ſoap.

That I might ſee if ſoap had any effect on lime and ſalts mixed in equal quantities.

Exp. 85. Sept. 23. Sixteen grains of cloth were put into 2 oz. of water, in which was diſſolved half a drachm of ſalts, that had been procured from equal parts of quick-lime and pearl aſhes. The ſame quantity of cloth was put into another mixture of the ſame kind, with the addition of half a drachm of ſoap. Nov. 15. Both pieces of an equal colour, both ſtrong, and both had loſt 1 gr. That in the ſoap was ſofteſt.

I have in theſe experiments related the facts as they appeared to me, and not the concluſions which may be drawn from them. Experiments, and the reaſonings on them, ought, in my opinion, always to be kept ſeparated, that every one may have it in his power to judge, whether the latter naturally and juſtly ariſe from the former. Let us now ſee what aphoriſms or corollaries may be fairly drawn from the foregoing experiments. I could wiſh more of theſe had been made, that thoſe might have been eſtabliſhed with a greater degree of certainty. I endeavoured to ſupply their number by their accuracy; for theſe experiments were all repeated a ſecond time. The firſt accounts of all arts and ſciences, have ever been imperfect; that will be excuſe ſufficient for what failings are met with here. But let it be remembered, that theſe firſt rude attempts have puſhed on and helped others to bring theſe arts to greater perfection.

Corol. 1. Water appears by Exp. 67. & 81. to diſſolve ſomething in the cloth, to make it lighter, and to have power, though a weak one, to whiten cloth. If brought to boil, it would ſeem to have a tendency to weaken cloth. Water, then, may juſtly be ranked amongſt the bleaching menſtruums.

Cor. 2. The mineral acid ſpirits, viz. oil of vitriol, ſpirit of nitre, and ſpirit of ſea ſalt, when diluted with a ſufficient quantity of water, extract from the cloth ſomewhat of an oozy ſubſtance, heavier than the acid mixture, as moſt of it falls to the bottom; whiten cloth, tho' not ſtrongly; and do not weaken it. The oil of vitriol whitens moſt, ſpirit of nitre next, and ſpirit of ſea ſalt, the leaſt of the three. They likewiſe make the cloth rough and hard.

Cor. 3. Pearl aſhes extract ſomething from the cloth; ſend up a conſiderable quantity of air.bubbles during the ſolution; make it whiter, though with a yellow caſt; but do not ſeem to have any tendency to weaken cloth when kept in the lye. Their power of whitening is ſtronger than that of the mineral acids, but not ſo ſtrong as lime, or a mixture of lime and pearl aſhes. I never could diſcover that they weakened cloth in the leaſt, although it was dried with the lye in it. This is contrary to the general opinion. The reddiſh colour that the lye acquires, and gives to cloth, ariſes from the particular action of alkaline ſalts on the juice of vegetables: for it will appear afterwards, that lint ſteeped in water, affords a pale-coloured tincture; but whenever alkaline ſalts are added to it, the tincture becomes red. The colour, then, is no ſufficient proof of the ſtrength of ſuch tinctures as are drawn with alkaline ſalts.

Dr. Hales has obſerved, that alkaline ſalts, though they have no effect on the hard calculi formed in the human bladder or kidnies, will diſſolve the ſoft ſtones that are found in the gall-bladder.

Cor. 4. Muſcovy aſhes have a remarkable power in whitening cloth, but they weaken it much. A bleacher told me, that he once attempted to bleach with theſe aſhes alone, but all his cloth was ſoon eat into holes.

Cor. 5. Marcoſt aſhes extract more from the cloth, whiten it more, and weaken it leſs, than Muſcovy aſhes do when uſed in the ſame quantity. The cloth in Exp. 59, was rather weaker than that in Exp. 58; but there was a half more of the Marcoſt than of the Muſcovy aſhes. Caſhub gives cloth a redder dye than the former, and weakens it as much.

Cor. 6. Stone-lime water whitens more, though it gives the cloth a yellow caſt, weakens more, and extracts more out of the cloth, than any of the former materials. This is ſufficient to deter any perſon from uſing this material by itſelf.

Cor. 7. Oyſter-ſhell lime water enjoys all theſe properties in a much ſtronger degree than the ſtone-lime water; and therefore ought to be deemed the moſt expeditious, but moſt dangerous material for bleaching that is yet known.

Cor. 8. Alkaline ſalts added to lime, diminiſh its power of weakening and corroding cloth; and that in proportion to the quantity of theſe ſalts added to the lime. This compoſition, as it is not ſo dangerous as lime alone, ſo it is not ſo expeditious in whitening. When equal parts of each are uſed, the whitening power is ſtrong, and the weakening power not very conſiderable ; ſo that I imagine they might be uſed with ſafety, in the proportion of one part of lime to four of pure alkaline ſalts, to bleach cloth. This fully accounts for an obſervation made by all bleachers, That the bleaching ſalts, when mixed together, operate ſafer and better, than when uſed ſeparately. For the corroſive power of the Muſcovy, Marcoſt, and Caſhub aſhes is corrected by the pearl aſhes, and the whitening quality of the latter is increaſed by that of the former.

There is not a more corroding ſubſtance, with regard to animals, than alkaſine ſalts and lime joined together, eſpecially when fuſed in the fire. This is the compoſition of the common cauſtic. But lime, and lime-water alone, preſerve animal ſubſtances in a ſound entire ſtate. It appears then very ſurpriſing, that ſalts and lime ſhould be found ſo little deſtructive to cloth, when lime, or lime-water alone, deſtroy it ſo remarkably. And yet this appears perhaps ſtronger than any other fact, from the whole of the foregoing experiments. So dangerous it is to depend altogether on analogical reaſoning.

This corollary is further confirmed, if that is neceſſary, by a paper, which, by accident, fell into my hands long before I had made theſe experiments. It lays down a method of bleaching ſafely with lime, as practiſed by the perſon who wrote it. My prejudices were ſo ſtrong againſt the uſe of lime, in any ſhape, before I had tried theſe experiments, that I had not then ſo good an opinion of the method, as I now have. As it contains many judicious obſervations, I ſhall give it as it was delivered me.

Method of bleaching with lime.

" Firſt, I ſteep the cloth in warm water for " twenty-four hours, then clean it in a waſh- " ing mill, of all the dreſſing, or ſowen, as " the vulgar term it. Afterwards I buck the " cloth with cow-dung and water, and bleach " it with this for three days; then clean it " again, and boil it with a lye made of Caſhub " aſhes. A pound to each piece of 18 or 20 " yards long is ſufficient. This I do twice, as " no lime ought to be given to cloth before it " is a full third whitened; as it by no means " advances the whitening of the cloth, but, on " the contrary, protracts it: for, inſtead of " looſening the oil and dirt in the cloth, when " brown, it rather fixes them; juſt as when " fine cloth is bucked with over-warm lyes in " the firſt buckings. Lime is by no means fit " for diſcharging the oil in the cloth, but for " cleaning it of the dead part, commonly " called Sprat. The cloth being cleaned, is " laid upon a dreeper. It muſt not be drier " before bucking with lime, otherwiſe it will " take in more than can be got out again be- " fore the next application: for as I have ob- " ſerved already, that lime is only fit for diſ- " charging the dead part, bucking thus wet " makes it reſt on the outſide of the cloth. I " take a lippy of the fineſt and richeſt powdered " lime that can be got, of the brighteſt white

" colour, as poor lime does more hurt than
" than good, to 30 pieces of the above lengths;
" and make a cold lye of it, by ſtirring and
" pouring water off the lime, until all be diſ-
" ſolved, but the droſs, which is thrown
" away: then I add a little ſoap, which makes
" the lye have the neareſt reſemblance to milk
" that breaks in boiling, of any thing I can
" think of: for this ſoap blunts the hotneſs of
" the lime. Then I take the cloth, and dip it
" in the lime-lye, and that moment out again,
" and lay it on a dreeper until it be bucked;
" then put it on the field, watering it care-
" fully; for if allowed to dry, it is much
" damaged. This is done always in the morn-
" ing; as it cannot be done at night, in regard
" of the hot quality of the lime, which ſoon
" heats the cloth, and tenders it. If a hot
" ſunſhine follows, it has great effect; for lime
" is juſt like all other materials for bleaching,
" that have more or leſs effect according as the
" weather is good or bad. I take it up the
" ſecond day after bucking, and give it a little
" milling or hand-bleaching, or bittling, com-
" monly called knocking; and lay it on the
" field again, watering it carefully as before.
" The effect is more viſible the ſecond than
" the firſt day. As all cloth when limed ſhould
" have a great deal of work, otherwiſe more
" than half the effect is loſt; and not only
" that, but a great deal of labour and pains
" is requiſite to take the lime out of the cloth
" again; it muſt never be expoſed on the Sab-
" bath day, but carefully kept wet always
" while uſed in this way. Thus bucking for
" three

" three or four times at moſt, is ſufficient for " any cloth, except that made of flax, pulled " either overgreen, or which grows in a droughty " ſeaſon, or perhaps not ſo well heckled as it " ſhould be. This ſort occaſions great trou- " ble and expence to the bleacher. But the " moſt effectual and expeditious way I ever " found for this kind, was, after boiling, to " take a little of the warm lye, and mix a " very ſmall quantity of lime with it, and draw " the cloth through that as hot as poſſible, " and put it on the field directly, watering it " carefully. This will clean it of the ſprat " ſurpriſingly. Then I boil it with pearl " aſhes, and give it the laſt boil with ſoap.

" There are innumerable miſtakes in the uſe " of lime committed by the vulgar, who are " ignorant of its quality and effects. They " know only this in general, that it is a thing " which whitens cloth cheap, and is eaſily pur- " chaſed; therefore they will uſe it. Some of " them begin whitening of their cloth with it, " which I have already obſerved to be wrong, " and given reaſons for it, and continue it until " the cloth is bleached; give it a boil or two " at moſt, and then waſh it up while the " groſs body of the lime is in the ſubſtance of " the cloth. This makes limed cloth eaſily " diſtinguiſhable from unlimed; as the former " has a yellowiſh colour, and is full of a pow- " der. Beſides, as lime is of a very hot, cor- " roding nature, it muſt by degrees weaken " the cloth. The bad effects of this ſubſtance " do not end here. When the cloth is put on

" board, it contracts a dampneſs, which not
" only makes it yellow, and loſe any thing of
" colour it has, but directly rots it. And
" although it ſhould eſcape this, which it is
" poſſible it may, by a quick and ſpeedy paſ-
" ſage; yet whenever it is put in any ware-
" houſe, it will meet with moiſture there, eſpe-
" cially if the winter-ſeaſon ſhould come on
" before it is diſpoſed, or made uſe of. Theſe
" I take to be the principal reaſons for ſo much
" complaint in bleaching with this material."

The whole art and ſafety in uſing the lime, according to this method, depends on the junction of the alkaline ſalts, during the bucking, to the particles of lime which were on the ſurface of the cloth. I ſhould rather prefer their junction in the lye; as it may happen, that ſome parts of the cloth which have received the particles of lime, may not, for ſeveral accidents, receive thoſe of the ſalts. That lime is not ſo proper in the firſt buckings, I very much doubt; as it is uſed in the foreign materials, according to the Dutch method, from the beginning. The breaking of the lime-water, when ſoap is mixed with it, is owing to the former being a hard water. This will be fully explained in the following ſection. It is not ſurpriſing that cloth bleached with lime alone ſhould, though well dried, contract moiſture, when we conſider the ſtrong attraction or affinity that there is betwixt lime and water.

I have been aſſured, that, in whitening yarn at Mancheſter, there is always a fourth part of lime added to the ſalts. I have diſcovered that it is uſed in the ſame way in this country. I know no objection to it, but that of its being againſt law.

Cor. 9. Lime-water, with a grain and a half of pearl aſhes added to each ounce, hurts cloth but very little, and whitens very much. This is a mighty cheap compoſition, and therefore deſerves the conſideration of bleachers.

Cor. 10. The effects of theſe different bleaching materials on cloth are increaſed by heat. They operate ſtronger when kept in a heat nearly equal to that of the human body, than in the heat of our atmoſphere in the ſummer; they operate ſtill more ſtrongly in the heat of boiling water, provided that heat is brought on by degrees. This is eaſily accounted for, when we conſider, that the inteſtine motion of fluids is augmented by heat whereby the impetus or momentum of thoſe ſolvents become ſtronger, and conſequently their effects ſooner produced.

Cor. 11. Thoſe materials that whiten ſooneſt, ſeem to extract moſt out of cloth, and to weaken it moſt ſpeedily; while thoſe that whiten ſlowly, extract but little from cloth, and therefore do not weaken it. This general rule admits, however, of many exceptions.

Cor. 12. Great plenty of air ariſes during the operation of the menſtruums on cloth. This ſhows, that there is ſome ſubſtance, which contains plenty of fixed air, diſſolved, and ſeparated from the cloth. Dr. Hales obſerved great plenty of air-bubbles ariſing from calculi, while they were diſſolving in ſoap-lyes.

Cor. 13. Acid and alkaline ſalts loſe, in the ſame proportion, as they operate on cloth, their acid and alkaline taſte, and appear to be ſheathed or deſtroyed by a junction with the ſubſtance they extract.

Cor. 14. Muſcovy aſhes, having the ſame proportion of pearl aſhes added to them as are uſed in the bleachfield, ſeem to loſe their corroding quality in a great meaſure. The common practice of the bleachfield was ſufficient to have taught this. The linen-bag, through which the lye is ſtrained, will ſerve for two years.

Cor. 15. Pure ſea ſalt does not whiten cloth, but opens, thins, and weakens it. Hence kelp aſhes which contain about a fourth part of ſea ſalt, muſt have the ſame effect. This is one reaſon, among others, why the Iriſh cloth is ſo thin and weak, as the kelp aſhes are generally uſed by them in the firſt buckings. Their moſt ſkilful bleachers have laid it entirely aſide, and uſe only the Caſhub aſhes. How the kelp aſhes may be freed from the ſea ſalt, I have conſidered in a former ſection.

Cor. 16. Waſhing with warm water and ſoap, and rubbing with the hands, are not capable of taking out all the acid or alkaline ſalts out of the cloth that has been ſteeped in them. It is only to be done by alkaline and acid ſalts.

Cor. 17. Cloth boiled in old lye gains conſiderably in weight, inſtead of loſing. Hence it would appear, that old lye is not ſo proper for ſteeping, the deſign of which is to take out the dirt and dreſſing.

Cor. 18. Cloth regularly watered, and expoſed to the influence of the air, loſes conſiderably of its weight, even though it has been well waſhed and rubbed in ſoap and water. This ſhews, that the air, ſun, and winds exhale ſomething, that waſhing and rubbing cannot take out; and therefore that the latter can never ſupply the place of the former, and be attended with the ſame advantage.

Cor. 19. Cloth, during the proceſs of putrefaction, turns blackiſh, throws off a great deal of black matter, and is weakened. Theſe effects muſt depend on the quickneſs and degree of putrefaction. Hence it is long before the putrefaction of plain water weakens cloth. Hence great care muſt be taken, that no corrupted butter-milk ſhould be uſed in the bleachfield: A circumſtance too little attended to. The ſame caution muſt be obſerved with regard to the time at which the ſouring proceſs ends; for immediately to that ſucceeds the procreſs of putrefaction.

Cor. 20. Caſtile ſoap appears to be a very weak bleaching material, and not to correct the corroding quality of Muſcovy aſhes or lime. It may however, be attended with other advantages. I find that it keeps the cloth ſoft. Mr. Chryſtie ſays, that cloth, when ſoaped, keeps longer moiſt, and is eaſier cleaned from the ſtain of a dirty foot.

Cor. 21. Buttermilk ſeems to have ſome gentle tendency to whiten cloth when yet brown. To cloth already white, it would ſeem to add ſomewhat, and to recover, in ſome degree, its ſtrength when impaired. By its fermentation the acid particles are diſengaged, and uniting with the abſorbent earth left in the cloth, render it ſoluble in water.

Quær. What effect will the juice of onions, leeks, or celery, have on cloth? They appear by experiment to have a gentle power in diſſolving the ſtone.

Quær. What effect will ſhell-marl have on cloth?

Theſe are all the experiments which I have made with regard to the effects of different bodies on unbleached cloth. Though few, they are ſufficient, I hope, to ſettle the genuine effects of theſe bodies; to teach the bleacher what he is to chuſe, and what to reject; how to balance ſafety and expedition, that his method may not become too expenſive by ſtudying only the former, or too dangerous by purſuing too eagerly the latter; and what is of greateſt importance, by what ſteps the art is to be advanced. But this is not all. The uſe of theſe experiments may be rendered far more extenſive. They teach the varied effects of various bodies, when applied to one another. They increaſe the ſcience of nature, and lead us to its true philoſophy. They heighten our admiration of its great author.

SECT. II.

The cauſe and effects of hard water, and the methods of ſoftening it.

THERE is no ſubject ſo often mentioned, and ſo little underſtood, as the cauſe of hardneſs in water: there is no ſubject of greater importance to the bleacher, or indeed to general uſe; there is no ſubject, of equal moment, that has been leſs conſidered, in an experimental view, than the preſent; for it lies, ſo far as I know, yet untouched. Theſe conſiderations induce me to undertake it. We have hitherto been contented with a ſhowy theory, how well founded, the following experiments will make appear, that ſea ſalt, if not the only, was the moſt general cauſe of hardneſs in water. Even experiments helped to corroborate this opinion; but experiments made with materials not well underſtood, and therefore deceitful.

The regular method of proceeding in this inquiry, ſeems this, To try whether we can ſoften hard water, by mixing different materials with it, or treating it in different ways; then to endeavour to harden ſoft water; and, laſtly, from theſe experiments, and from others, to diſcover the true cauſe of the hardneſs in water.

It is neceſſary to define our terms. Water is generally underſtood to be hard, when ſoap, agitated in it with the hand, does not raiſe a froth or lather on the ſurface, nor diſſolves equally through the water, but curdles, or ſeparates into a thicker and thinner part; the former of which mounts to the ſurface, and there remains like a white oil, while the water continues tranſparent below. Hard water has other diſtinguiſhing marks; ſuch as, not ſoftening peaſe that are boiled in it; boiling fiſh better than ſoft water; extracting leſs ſtrength out of malt in brewing; preſerving the colour of greens boiled in it, better than ſoft water; and not taking the dirt out of foul linen ſo well when waſhed in it. Theſe I think too vague and undetermined to be taken as ſtandards for experiment. The curdling of ſoap I ſhall then make my fixed point; on one ſide of which the ſoft waters lie, and on the other the hard. We ſhall call this the curdling point. This dandard of hard and ſoft water is more certain than any of thoſe commonly known; and has the advantage of being underſtood by every body. Our experiments will furniſh us with a ſubſtance which ſhows the hardneſs of water long before ſoap can diſcover it; but not more certainly. We ſhall make the proper uſe of it afterwards; and follow, at preſent, the common ſtandard of hard and ſoft waters. The hard water uſed in the following experiments, was taken in July from a well when it was low.

The water which flows from the pipes diſſolves ſoap eaſily and equally; but this water curdles it directly, and in half a minute the ſoap riſes to the ſurface. In the former water many air-bubbles ariſe on the ſurface, during the agitation, and remain for a long time; but in the latter few are to be ſeen, and thoſe immediately diſappear. In the former ol. tart.

p. d. makes no lacteſcency or milky colour; but it does in the latter. The ſoft water was ſpecifically lighter than the hard water; for a piece of glaſs, that weighed in the former 3 dr. 18¾ gr. weighed in the latter half a grain leſs. To diſcover how far beyond the curdling point this hard water was, the following trial was made.

Exp. 84. Three parts of ſoft water and one of hard were mixed, and diſſolved ſoap equally; ſo did two of the former to one of the latter. Equal parts of the ſoft and hard broke the ſoap; but I obſerved through the glaſs that the ſolution was not quite ſo equal as the former. When the ſoap was mixed with two parts hard to one of ſoft, the ſoap aroſe; but ſeemed to ſeparate with ſome difficulty: and the line of ſeparation was not ſo diſtinct as in the following mixtures, nor the liquor below ſo clear. When it had ſtood half an hour, I mixed the whole together with a ſpoon, and it never afterwards ſeparated. This laſt, then, I muſt look on as the firſt degree of hard water, and the mixture before it as the laſt degree of ſoft water. When three parts of hard were added to one of ſoft, the curdling was quick, the line of ſeparation diſtinct, and when mixed together, it again ſeparated. This ſhews how far beyond the curdling point lies the hard water, which I uſed in theſe experiments.

Fire is generally thought to ſoften hard water. One is naturally led to think ſo, as boiled water has a ſofter taſte than cold water, when made into punch. To aſcertain this point, Exp. 85. I tried the hard water when it was ſo warm that I could juſt hold my hand in it; but the ſoap curdled as faſt as before. After it had boiled a quarter of an hour, it was ſtill the ſame. There was no alteration, as to this quality, after it had cooled for two hours. Eight Engliſh pints were boiled into one; it ſeemed then much harder than before. Boiling, then, appears rather to harden this water, than ſoften it.

It is the general opinion, that all waters are ſoftened by putrefaction, and that ſtagnation and expoſition to heat are attended with a degree of it. That I might bring this opinion to the teſt of fact,

Exp. 86. July 1. I expoſed 4 Engliſh pints of hard water in an earthen veſſel near a conſtant kitchen-fire. July 14. Still ſweet and hard. 24. Still the ſame, and continued ſo till it was thrown out, Nov. 11. as incapable of corruption. At that time it was reduced to the half; and, inſtead of being ſofter, was twice as hard as at firſt; for it required twice its quantity of ſoft water to make it break ſoap.

When I ſaw that this water had no appearance of becoming putrid, I put, July 24. into the ſame quantity of the ſame water, in another pot, a large handful of dung to haſten its putrefaction. The water had a gentle corrupted ſmell for two or three days; but, after that, became ſweet, and continued ſo, as likewiſe hard, on the 11th of November, when it was thrown out.

That I might overcome this antiſeptic quality in hard water, Exp. 87. Nov. 11. Into a quantity of this water I put ſome fleſh, and into the ſame quantity I put the ſame quantity of fiſh. Dec. 10. Both waters were very putrid. The water in which the fiſh had been, was now ſoft; that with the fleſh was ſtill hard, though a ſmall degree of heat made it break the ſoap too. By another experiment I found, that hard water, putrified by the aſſiſtance of fleſh, became entirely ſoft. Hence we learn, that putrefaction ſoftens hard water; and every tendency towards that proceſs muſt have a proportionate degree of that effect. But hard waters appear to reſiſt that change very powerfully.

It is generally thought, that hard water filtered through ſand becomes ſoft. I was of the ſame opinion *, and had not truſted to theory alone for it. But being profeſſedly engaged in this purſuit, and having made the experiment more exactly, and carried it farther than what I had done before, I find that this effect of ſand is limited.

Exp. 88. A quantity of ſea ſand was well waſhed with ſoft water, each parcel three times, and then put into two caſks that were ſet above one another. There was a hole in the centre of the bottom of the upper caſk, by which the water was to paſs into the lower; and a hole in the under part of the latter, by which the water was to iſſue through a pen. When the ſand was wet with water, I obſerved it decreaſed conſiderably in its volume. This remarkable property of ſand, which ariſes from a cloſer

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* Vid. Dunſe Spaw, ſection on water.

a cloſer diſpoſition of its particles by the water as it flows in, is wiſely deſigned, by the author of nature, to anſwer ſeveral valuable ends. That I might waſh out all the ſalts or ſoluble parts from the ſand, ſoſt water was filtered through it. The water came off hard for two days; but after that became ſoft. The hard water was then paſſed through the ſand, and it came off entirely ſoft; nay more ſo than the town-well water; as it ſeemed to diſſolve ſoap better, when equal parts of it and hard water were mixed, than the town-well water had done in the ſame proportion. It appeared ſofter from the following trial. Three parts of the filtered hard water were mixed with one part hard water; the town-well water was mixed in the ſame proportion. Ol. tart. p. d. produced a lacteſcency in the latter, but not in the former: but when there were two parts of hard water to three of filtered, a lacteſcency juſt began to appear. But how cautious ought we to be in drawing general concluſions from the apparent ſucceſs of an experiment! The water, running through a quill in a conſtant ſtream, continued ſoft for twenty-four hours; but after that it turned hard, and remained ſo.

This is eaſily accounted for. The ſubſtance, whatever it is, which makes water hard, finds great difficulty in paſſing through the interſtices of the ſand, but is not altogether ſtopped. Hence, by degrees, it is waſhed down by the water, and lies ready to impregnate the ſoft water which is iſſuing through the quill, while its place is ſupplied by that immediately above it; and ſo in a continual ſucceſſion. Thus the water muſt after a certain time become hard. From this experiment we may conclude, that ſoft ſprings at leaſt are not ſupplied by the ſea, as ſea-water is hard.

This method of filtration may ſtill be very proper to free impure waters of the filth they contain, or of their earthy and oleaginous particles, and clarify them. The water before it was filtered, was not only hard, but had a bad taſte. Its taſte after filtration was quite altered: it was nauſeous before, but had a ſaline ſweetneſs after.

I have heard, that great quantities of chalk thrown into wells of hard water made it ſoft. With this view I tried the following experiment.

Exp. 89. Powder of chalk, mixed with hard water, did not ſoften it. When boiled for a quarter of an hour in hard water, and allowed to ſubſide, the clear liquor was no ſofter than before. It does not therefore ſoften water, by any change that it makes on the water from an addition of its ſubſtance: but if it has that effect, ii muſt act as a filter. This appears to be its method of acting: for hard water filtered thro' a height of chalk of two inches, came off ſo ſoft, that it broke ſoap; but ol. tart. p. d. produced a lacteſcency, in three parts of it mixed with one part hard water. The water filtered through the chalk ſo ſlowly, that I ſhould be afraid of its not allowing the water to paſs in any quantity, if the ſpring be in the bottom of the well. This was the caſe, as I am told, in a well where this experiment had been tried;

for, afterwards, in dry weather it was always ſo low, that they could get no water out of it.

Exp. 90. Some hard water was clarified, by having the white of an egg beat up with it, and afterwards boiled. The ſoap broke pretty well at firſt in it; but, on ſtanding ſome ſeconds, it curdled, and roſe to the ſurface.

Lime was tried to ſoften hard water, and not without ſome hopes of ſucceſs: for as it is thought a great corrector of the muriatic acrimony in the blood, it might have the ſame effect on the muriatic ſalts, the ſuppoſed cauſe of the hardneſs of water.

Exp. 91. Lime was mixed with hard water, but it was not ſoftened by being made into lime-water. The ſame lime-water ſtood till the calcarious particles were all evaporated, but ſtill the water preſerved its natural hardneſs. We ſhall ſee preſently that the real effect of lime is very different from the imagined one.

Exp. 92. It is generally thought, that fern ſoftens water; and it is often uſed with that deſign: but infuſing ſome of that vegetable in warm hard water, and letting it ſtand all night, I could not diſcover any ſuch effect. The ſalts in it, though they do not ſoften the water, may perhaps quicken the effect of water, when it is to operate as a menſtruum, to looſen the oils of vegetables: for it is in the ſteeping of lint that fern is uſed.

Let us try what experiments made on no previous theory will produce.

Exp. 93. The extract of bark, of gentian, and of centaury, appeared, at my firſt trial, to have a power of ſoftening hard water; but, on repeating the experiment, I found, that the dark colour of the ſolutions, or the mixture of ſome alkaline ſalts with theſe extracts, which ſometimes happens, had miſled me. Nor did I ſucceed better in ſoftening hard water with the extract of wormwood, of black hellebore, of chamomile, or of logwood; with rhubarb, Bohea-tea, lintſeed, oak bark, gum Arabic, or gum ammoniac.

Exp. 94. A ſolution was made of 2 ſcrup. of blue pearl aſhes in 2 oz. of ſoft water. Sixty drops of this ſolution, mixed with a ſpoonful of hard water, diſſolved ſoap without curdling. A hundred drops of a ſolution, that contained juſt 5 gr. of blue pearl aſhes, made four ſpoonfuls of hard water ſoft; but the ſoap curdled on the addition of another ſpoonful. We have then found a ſoftener of hard water where it was not expected. This experiment led me to try the following.

Exp. 95. Twenty drops of the ſpirit of hartshorn ſoftened two ſpoonfuls of hard water. The ſame number of drops, mixed with the ſame quantity of hard water, and allowed to ſtand for two or three days till the ſmell of the ſpirit was gone, broke ſoap as well as with the recent addition. That I might find out the preciſe quantity of dry volatile ſalt, I diſſolved 2 gr. in half a ſpoonful of hard water, which broke ſoap well; but when I added another half-ſpoonful, it was with ſome difficulty that it broke ſoap: but after it had done it, there was no ſeparation. Thus we have found two ſubſtances, the fixed and volatile ſalts, which have a remarkable effect in ſoftening hard waters.

ters. How far theſe may be applied with ſafety to the common uſes of life, we ſhall afterwards conſider.

Let us next endeavour to diſcover what ſubſtances make water hard. I could not procure diſtilled or rain water in quantity enough to ſerve me in all the following experiments: but the moſt important were performed with the latter. We ſhall begin with the mineral ſubſtances.

Exp. 96. A large key was infuſed in ſoft water for a day: it made the water yellow, and gave it a ſtrong chalybeate taſte, but did not harden it. Neither did a red-hot iron quenched ſeveral times in ſoft water. Copper infuſed in ſoft water for two days, gave it a mineral taſte; but did not change it into hard water.

Sea ſalt is commonly thought, if not the only, at leaſt the moſt general cauſe of the hardneſs in water. It was natural to think ſo, when we found, that common ſea ſalt curdled ſoap diſſolved in water, and conſidered how general an ingredient it is in all waters. But the following experiments will ſhew us, that this is not the effect of ſea ſalt, but of the impurities mixed with it. The ſea ſalt, which I uſed, is a particular kind that is only made on Sunday; and therefore called Sunday-ſalt, or great ſalt, from the largeneſs of its grains. It cryſtalizes at a time when the fire is low, and the ſea water not altogether evaporated, as it is in the common way of making ſalt. It contains leſs of the bittern than the common ſea ſalt, and has therefore a particular ſweetneſs. It is the moſt proper for the table and for experiments.

Exp. 97. A grain of pure ſea ſalt was diſſolved in 4 ſpoonfuls of rain-water. This ſolution diſſolved ſoap well, and did not turn lacteſcent with ol. tart. p. d. Some drops of a ſolution of quickſilver in aq. fortis made a great lacteſcency in it; this lacteſcency was juſt perceptible when the ſolution of the ſea ſalt was diluted with ſixteen times its quantity of water. This ſolution of quickſilver, then, does not diſcover hard waters; it only diſcovers ſea ſalt in water; and that when in a very ſmall proportion, 1 gr. in 3 Engliſh pints of water.

Exp. 98. A ſpoonful of rain water, with 5 gr. of pure ſea ſalt diſſolved in it, continued ſoft. With 6 gr. there appeared a little curdling, but a little more agitation diſſolved the ſoap. This curdling ſeems to be owing to ſome remainder of the bittern; for 2 gr. of common ſea ſalt made water as hard as theſe 6 gr. had done. The bittern has this quality ſo ſtrong, that a fourth part of a grain of the bittern ſalt hardens a ſpoonful of rain-water. The ſpirit of ſea ſalt ſaturated with an alkaline ſalt, does not harden water. The proof ſtill becomes ſtronger, when a ſmall lacteſcency appears on dropping ol. tart. p. d. into a ſolution of 5 gr. of pure ſea ſalt in a ſpoonful of rain-water. From theſe facts it appears, that pure ſea ſalt has no hardening quality, and that the bittern has it in a very ſtrong degree. The hardneſs of waters can never be owing to the former ſalt, as the taſte can diſcover a ſmaller admixture of it than what would be neceſſary to have that effect, if it ever has any ſuch.

Thus pure and impure ſea ſalts appear, by experiment, to have very different effects on bodies. I am afraid this has not been ſufficiently attended to; and the effects of the bittern have often, unjuſtly, been attributed to ſea ſalt. I have diſcovered, ſince I made the preceding experiment, that Lemery has long ago made the proper diſtinction betwixt theſe ſalts *.

The common Epſom ſalt, ſold in the ſhops, is the bittern or ſecond kind of ſalt in ſea-water.

Exp. 99. Five grains of Epſom ſalt hardened 2 ſpoonfuls of ſoft water ſo much, that it required to be diluted in 16 ſpoonfuls, before it began to break ſoap. A great lacteſcency happened betwixt this ſolution and ol. tart. p. d.

Exp. 100. Alum renders ſoft water very hard; ſo that 5 gr. required 20 ſpoonfuls of ſoft water before it would break ſoap. Ol. tart. p. d. made a lacteſcency.

Exp. 101. Salt of ſteel hardens water. I was obliged to dilute 10 gr. in 45 ſpoonfuls of ſoft water to make it break ſoap. Every one knows, that alkaline ſalts render a ſolution of this ſalt turbid and green.

Exp. 102. Blue vitriol or ſalt of copper hardens water ſo much, that 5 gr. required to be diluted in 35 ſpoonfuls of ſoft water to make it break ſoap. Alkaline ſalts turn a ſolution of this turbid and blue.

Exp. 103. Vitriolated tartar got from the apothecary's ſhop hardened water; but finding that

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* Cours de chymie, p. 307.

that it had a ſtrong acid taſte, I made ſome, by dropping 40 drops of ſpirit of vitriol into a ſolution of ſalt of tartar. When the ſaturation was fully completed, I put the whole into two ſpoonfuls of ſoft water, and it diſſolved ſoap very well. No lacteſcency.

Exp. 104. Five grains of the ſugar of lead hardened water. When diluted in 24 ſpoonfuls, it began to diſſolve ſoap. The alkaline ſolution made a lacteſcency in it.

Exp. 105. Crude ammoniac ſalt, borax, ſal prunel, ſal polychreſt, gum ammoniac, chamomile flowers, oak bark, Peruvian bark, did not harden water. Nor did oil of tartar produce a lacteſcency in their ſolutions.

Exp. 106. Five grains of cream of tartar hardened ſoft water; but when diluted in ſix ſpoonfuls, it diſſolved ſoap. No lacteſcency.

Exp. 107. Five grains of ſalt of amber made water ſo hard, that I was obliged to dilute it with 50 ſpoonfuls before it would break ſoap. No lacteſcency.

Exp. 108. Twelve drops of ſpirit of vitriol required eight ſpoonfuls before it would diſſolve ſoap. One drop of oil of vitriol required to be diluted in ſix ſpoonfuls, the ſame quantity of ſpirit of ſea ſalt in five ſpoonfuls, the ſame of nitre in three ſpoonfuls of ſoft water, before ſoap could be equally diſſolved. A teaſpoonful of vinegar required eight large ſpoonfuls of ſoft water to make it break ſoap. The alkaline ſolution raiſes an efferveſcence, though it does not make a lacteſcency with theſe acids.

Exp. 109. Some powder of chalk was well mixed with cold ſoft water: it was poured off after the chalk ſettled and diſſolved ſoap. Soft water boiled with chalk for half an hour, was not hardened by it. Some clay wrought for ſome time in water, and allowed to ſubſide, did not harden it. Lime renders water remarkably hard.

Exp. 110. Lime-water that was made with ſoft water, and had ſtood for three or four days over a great quantity of lime, which had before afforded ſome pints of lime-water, curdled ſoap at once, and became milky with the alkaline ſolution. One ſpoonful of this lime-water required ſix ſpoonfuls of ſoft water before it broke ſoap. Ten ounces of lime-water was boiled into two, but it diſſolved ſoap no better than before. The ſame lime-water, when it had become vapid with ſtanding, broke ſoap as well as ſoft water. The hardneſs of lime-water appears plainly to be owing to the ſoluble parts of the lime; and the more water contains of theſe, it muſt be the harder. We cannot know from this the real quantity of theſe particles contained in the water; but we may know the proportionate quantity; and of courſe the comparative ſtrength of different lime-waters. Let us, then, try to determine, by this teſt, an intereſting queſtion, Whether double or triple lime-water is ſtronger than ſingle?

Exp. 111. I made ſome lime-water; in half an hour I poured moſt of that ſingle lime-water upon freſh lime; about the ſame time after I poured moſt of that double lime-water upon freſh quick-lime; and ſo made a triple lime-water. When they had all ſtood about two hours, a ſpoonful of the ſingle lime-water required to be diluted with nine ſpoonfuls of ſoft water, before it would break ſoap; the double required 12, and the triple 15. The times and force of agitation were, as near as I could make them, the ſame. I poured the triple lime-water again upon quick-lime. The other lime-waters were poured from the lime into open glaſſes. An hour and an half afterwards, the ſingle lime-water required 9 ſpoonfuls, the double 11, the triple 13, and the quadruple 17. This laſt experiment was made at twelve at night. Next morning the whole four lime-waters, having ſtood all night in open glaſſes, required but 9 ſpoonfuls, although the quadruple lime-water had ſtood over its lime all the night. This experiment agrees exactly with what I had formerly diſcovered by weighing their ſpecific gravities. A piece of glaſs weighed 2 dr. 23 gr. in town-well water; in ſingle ſtone-lime water it loſt a grain, and in triple a quarter of a grain more. This ſhewed the ſpecific gravity of the triple lime-water was greater than that of the ſingle, by a fourth of the difference betwixt the laſt and plain water. The lime-waters in this laſt experiment had ſtood for two hours, till they were entirely clear.

I repeated the former experiment again, and I ſtrained the waters, after they had ſtood an hour, through brown paper. The ſingle lime-water required 8 ſpoonfuls of ſoft water before it broke ſoap, the double 9, and the triple 11. I was reſolved to ſee how far it would go, and made a quadruple; but, finding it took no more than the laſt, I deſiſted.

That I might diſcover how long theſe different lime-waters would preſerve a difference in ſtrength, if kept in cloſe bottles.

Exp. 112. I made ſingle, double, and triple lime-waters, ſtirred them frequently for four hours, and then ſtrained them. The ſingle required 15 ſpoonfuls of ſoft water, the double 18, and the triple 20, before they broke ſoap. They were bottled, corked, and waxed over. After they had ſtood 10 days, they required the ſame quantity as before to ſoften them. When kept ſome days longer, the ſingle was ſtill of the ſame ſtrength, but the triple required only 18 ſpoonfuls of ſoft water.

As it may be objected to theſe experiments, That the water had not ſtood a ſufficient time over the lime, nor had they been frequently mixed together,

Exp. 113. I made two different quantities of lime-waters, with two parcels of the ſame quick-lime. I tried one of the lime-waters in the above-mentioned way, after it had ſtood without ſtirring for two hours. The other ſtood over the lime twenty four hours, and was frequently ſtirred. They were equally hard, and therefore equally ſtrong. Lime-water then made with unſlaked lime, need ſtand no longer than it is clear.

The concluſion, then, from theſe experiments, is, that lime-waters made with different lime, differ very much from one another; that double lime-water is ſtronger than ſingle, and triple than double; and that they retain their different ſtrengths, if kept from the influence of the external air; but if expoſed to it, in open veſſels, in a few hours become of equal ſtrength.

To try what effect alkaline ſalts had as to the ſoftening of lime-water,

Exp. 114. I poured on quick-lime ſome water, in which the fourth part, in proportion to the lime, of blue pearl aſhes had been diſſolved. The water had a ſharp, pungent taſte, and ſeemed to be about the hardneſs of the hard water, which, though hard, is much ſofter than lime-water. The ſoftening power of the alkaline ſalts, appears yet better from the following experiment. One ounce of potaſhes diſſolved in two gills of water, and poured on an ounce of quick-lime, produced a very cauſtic liquor, which broke ſoap, but not ſpeedily. Lime-water is ſoftened by an addition of alkaline ſalts. From this experiment we may ſee the reaſon, why the ſoap mixed with the lye, which is a compoſition of lime and alkaline ſalts, is not curdled.

A table of the comparative power of bodies with regard to ſoftening and hardening of water.

Comparative ſoftening powers.

Filtration through ſand ſoftens in proportion to the length of its courſe.

Putrefaction ſoftens in proportion to its degree.

Volatile ſalt of hartſhorn ——	1

Fixed alkaline ſalts, though not of the ſtrongeſt kind	2

Comparative hardening powers.

Epſom ſalt	3
Alum	4
Salt of ſteel	4½
Blue vitriol	7
Sugar of lead	5
Cream of tartar	1½
Salt of amber	10
Oil of vitriol	18
Spirit of ſea ſalt	15
Spirit of nitre	9
The ſoluble part of lime	45

In computing the hardening power of theſe acid ſpirits, I have allowed 3 drops to be equal to a grain; which may ſerve very well in a general way of computation. But when we conſider, that there is but a part of theſe ſpirits real acid, and that thoſe which I uſed had been negligently kept, we ſhall ſee reaſon for attributing a very ſtrong hardening power to the real acid ſalts of theſe liquors. By the trials which I have made, there appears to be but 1 gr. of the ſoluble part of lime in 5 oz. of lime-water, which I reckon equal to 8 ſpoonfuls; and 1 ſpoonful was found to require 6 ſpoonfuls of ſoft water to make it break ſoap.

It muſt be obſerved, that all theſe artificial hard waters, except thoſe made ſo with acids, were rendered turbid or lacteſcent with alkaline ſalts. This will be found a general rule, That wherever ſoap is curdled, alkaline ſalts produce a change in the colour and purity of the water; becauſe both effects depend on the ſame cauſe. Hence ariſes a new ſtandard to help us to judge of the degree of hardneſs in waters. Let us inquire at what time this change of colour ariſes; it may, perhaps, diſcover a leſs degree of hardneſs in water than ſoap does.

Exp. 115. A mixture was made of equal parts of hard and ſoft water. This we found before not capable of curdling ſoap, and, therefore, called it the laſt degree of ſoft water. This ſoft water, on dropping ſome of the ſolution of pearl aſhes into it, turned as white as the hard water did with the ſame ſolution. When two parts of ſoft water and one of hard were mixed, a lacteſcency aroſe with the ſolution, but weaker than in the laſt. When three parts of ſoft were mixed with one of hard, a very diſcernible alteration of colour ſtill happened. Thus we ſee, alkaline ſalts diſcover a much leſs degree of hardneſs in water, than what ſoap does. Let us therefore call this degree of hardneſs in waters, whereby they are made to change their colour with alkaline ſalts, the lacteſcent point.

We are now on a better footing than what we were when we ſet out. We have gained two fixed points in hard waters, that will allow of compariſon. We may now divide all waters, with regard to this quality of hardneſs, into three ſorts. The firſt are thoſe which neither change with alkaline ſalts, nor curdle ſoap; the ſecond, thoſe which loſe their tranſparency with theſe ſalts, but in which ſoap is not curdled; the third ſort are thoſe where both effects happen. The firſt claſs are the ſofteſt of all waters, and the fitteſt for moſt uſes in life; the ſecond claſs, at leaſt the firſt degrees of that claſs, may do tolerably well in the common houſhold affairs, though not in the bleachfield; but the third ſort I condemn as hurtful, and improper in almoſt all caſes. The water which iſſues from the pipes of Edinburgh wells, is in the firſt claſs: for it not only breaks ſoap well, and retains its tranſparency when ſalt of tartar is mixed with it; but likewiſe ſhews no lacteſcency, when a ſolution of quickſilver in aqua fortis is dropped in it. By this laſt we diſcover, that if it contains any ſea ſalt, it muſt be in a leſs proportion than one grain to three Engliſh pints; too inconſiderable a quantity to be taken notice of.

The foregoing obſervation leads us likewiſe to another very material concluſion; which is, that the curdling of the ſoap is brought about by the alkaline ſalts, and not the oil: which two bodies, with a little lime and ſea ſalt, make up the compoſition of hard ſoap. The ſea ſalt has not that effect, as we proved before; and the lime is in ſuch a ſmall proportion, and mixed with alkaline ſalts, which we juſt now found ſoftened it, that it cannot be the cauſe of the curdling of ſoap. We have found, that neither natural nor artificial waters ever curdle ſoap, without having their compoſition altered, or viſibly affected by alkaline ſalts: it therefore follows, that the alkaline part of the ſoap is the part on which theſe hard waters work. Accounting for the lacteſcency with ſalt of tartar, is accounting then for the operation of ſoap. It is no wonder that hard waters produce their effect ſomewhat later on ſoap, as it is defended by the oil from their operation longer than the naked ſalts. As ſoap is a more compounded body than the ſalts, the circumſtances reſulting from a mixture of hard water with each muſt be very different.

We have diſcovered, in theſe experiments, three different cauſes of hard water; quicklime, acids, and neutral ſalts. This property in lime ſhall be examined by itſelf. Acid ſalts, ſuch as the oil and ſpirit of vitriol, the ſpirit of ſea ſalt, and that of nitre, vinegar, cream of tartar, and ſalt of amber, hardened water remarkably. Why they ſhould do ſo, is eaſily explained. The alkaline ſalts having a ſtronger tendency to the acid than to oil, quit the latter, and adhere to the former. Hence the artificial compoſition of ſoap is deſtroyed, and the oily part, ſeparated from the alkaline, floats like clouds, and at laſt, by its ſpecific lightneſs, riſes to the ſurface. The ſtronger the acid is, every thing elſe equal, the harder muſt it make the water. Hence the mineral acids, conſidering the great proportion of real acid in them, have the ſtrongeſt effects: but theſe can ſeldom or never impregnate natural waters, becauſe abſorbent particles are found almoſt every where; which would directly join the acids, and reduce them to neutral ſalts. In fact no acid water has yet been diſcovered.

This leads us to conſider theſe neutral ſalts as the general cauſe of hardneſs in water.

When I look back on theſe experiments, I cannot but obſerve one remarkable fact; which is, that none of the more perfect neutral ſalts compounded of an acid and alkaline baſe, render water hard; but that all the imperfect ſalts, compounded of an acid and abſorbent earth, or a metal, have this effect on water. Epſom and alum ſalts have an abſorbent earth for a baſe; ſalt of ſteel, ſugar of lead, and ſalt of copper, a metallic one. It is a fact known to all chymiſts, that when alkaline ſalts are poured on a ſolution of the imperfect ſalts, the acid quits the abſorbent earth or metal, and joins the ſalts; becauſe the power of attraction betwixt the acid and ſalt is ſtronger than betwixt the acid and earth or metal. But when thoſe alkaline ſalts are added to the ſolution of the more perfect ſalts, no change can happen; becauſe the alkaline ſalts, to which they are already united, attract the acid as ſtrongly as thoſe that are now added. It is the ſame thing then with reſpect to the alkaline ſalts, whether the acid is or is not joined to a metal or abſorbent earth, ſince it ſo eaſily leaves them. But the effects which follow will be different: for, in the former caſe, the liquor muſt loſe its tranſparency, at leaſt for ſome time, on account of the deſerted particles which float in the liquor; but in the latter no ſuch effect can happen, and the liquor muſt continue limpid.

Hence ariſes already a great preſumption, that theſe imperfect ſalts are the common cauſe of the hardneſs in waters, ſince the appearances in both caſes correſpond ſo exactly: for a curdling of ſoap, a lacteſcency, and precipitation, are obſerved in both natural and artificial hard waters. But it muſt ſeldom happen, that the hardneſs of waters is owing to a neutral ſalt, compoſed of an acid and a metallic baſe; conſidering how much oftener the acid muſt be joined to an abſorbent earth. The former does ſometimes happen: for the Hartfield water is very hard; and experiments ſhew, that it contains a ſalt of ſteel and no other. When this is the caſe, the water becomes a mineral water, and will ſoon diſcover itſelf by its mineral effects. In all hard waters, then, excepting the mineral, we may preſume, that there is an imperfect neutral ſalt.

This cauſe of hardneſs in waters accounts for the power which alkaline, fixed and volatile ſalts have of ſoftening theſe hard waters. Theſe two bodies unite themſelves with the acid, and throw off the abſorbent earth: the fixed ſalts conſtitute with the acid a perfect ſalt; which ſpecies of ſalts, as we already diſcovered, has no power of hardening water; and therefore the water becomes ſoft. The volatile alkaline uniting with the acid, conſtitutes an ammoniacal ſalt, or one like it; which we found likewiſe not to harden water; and therefore the hard water becomes ſoft. The water is rendered by that change on the ſalts more healthful; which we were not ſure of when the fact was firſt diſcovered.

Let us try how far experiment will ſupport this theory of hard waters: for I can allow it to be as yet nothing but a theory, though a plauſible one; ſince it ariſes only from a ſimilitude of effects betwixt natural and artificial hard waters. If this theory be true, we ſhall be able to exhibit to the eye theſe hardening ſalts, or at leaſt ſome part of them; by which we may diſcover, that the other part has been once preſent. Let us ſee what evaporation will give us.

Exp. 116. Four Engliſh pints of this hard water were evaporated to dryneſs, and left 26 gr. of a brown powder, which had a pungent ſaline taſte, and liquified in the air. This powder effervеſced with both vegetable and mineral acids; but it effervеſced likewiſe with a ſolution of alkaline ſalts. It muſt therefore be a compoſition of both acid and alkaline ſalts, or abſorbent earths; the latter of which ſeem to prevail, as the powder turned the ſyrup of violets green. Brown paper dipped in a ſolution of it, and dried, burnt like a nitrous match. Six grains and a half of the powder diſſolved in a pint of ſoft water, made it ſo hard, that it would ſcarcely diſſolve ſoap. In this reſiduum, then, we have diſcovered the hardening cauſe; but it appears, that about the half of it has been diſpelled by the evaporation. It is probable, that this volatile part is an acid, as the reſiduum ſeems to partake moſt of a contrary nature.

Let us ſee whether we cannot make this acid more fixed and more viſible by joining it to an alkaline baſe.

Exp. 117. Into four and a half gills of hard water, was dropped ol. tart. p. d. as long as any lacteſcency was made by it. During the addition of the alkaline ſalt, I obſerved through the glaſs a very great inteſtine motion in the liquor: ſome air-bubbles, though but very few aroſe; and the clouds diſperſed themſelves through the whole with a conſiderable motion. But no ſuch effect happened when I dropped the ſame ſolution into ſoft water. Here then is a a plain and diſtinct inteſtine motion or efferveſcence. The liquor, having ſtood all night, appeared tranſparent in the morning, and the bottom of the glaſs was covered with a whitiſh powder. The water now broke ſoap. When the whole was ſhaked, it turned white; which ſhews the milky colour is owing to this powder. The liquor was ſtrained through brown paper, and I had five grains and a half of white powder. To be ſure that this precipitation did not ever happen in ſoft waters, and that it was no part of the alkaline ſalt, I dropped the ſame quantity of ol. tart. p. d. into the ſame quantity of ſoft water; but no precipitation followed. This powder, when mixed with ſoft water, did not harden it; when kept in a ſtrong kitchen-fire for two hours, it was reduced to good quick-lime.

That I might diſcover the contents of the hard water, after the addition of alkaline ſalts,

Exp. 118. Three chopins of hard water were treated in the ſame way, and evaporated to 2 oz. of a red liquor. The firſt ſalt that ſeparated from the liquor weighed 15 gr. It turned ſyrup of violets green, and efferveſced with ſpirit of vitriol; marks of its being alkaline. More alkaline ſalts had been added than what were neceſſary. The next cryſtalliſation afforded ed me a ſcruple of a ſalt, which, tho' it ſeemed to be of an alkaline caſt, approached much nearer to the neutral ſtate than the former, gave ſtrong marks of a nitrous ſalt, and afforded me great hopes from the next cryſtalliſation. It ſucceeded accordingly. In a night's time I had half a drachm of fine white cryſtals, ſome of them an half-inch in length, and exactly like the regular cryſtals of nitre. They had a bitter cooling taſte; when joined to oil of vitriol, emitted ſtrong acid fumes, and corroded ſilver; when vinegar was poured in them, a few air-bubbles aroſe: but theſe ſeemed plainly to be owing to the alkaline liquor round them; for the cryſtals lay for ſome time, after the inteſtine motion ceaſed, undiſſolved at the bottom of the glaſs: when brown paper was dipped in a ſolution of them, it burnt, and ſparkled like the ſame dipped in a ſolution of ſaltpetre. Theſe characteriſtical marks, with its effects of turning fleſh red when boiled in the water, are ſufficient to prove it to be a real ſaltpetre; for theſe are the properties of that ſalt, and belong to no other. The liquor remaining was of a dark colour, and taſted like a ſolution of ſea ſalt.

The earth in this hard water we demonſtrated before to be of the calcarious kind, and convertible into lime. We have at preſent demonſtrated the acid of this hard water to be that of nitre. The chymiſts deny that ſuch an acid exiſts in nature, and affirm, that it is made from the vitriolic and an inflammable principle conjoined: but here we have found it preſent, and helped to volitalize it. Hoffman denies the exiſtence of nitrous waters, and ſays, that an inflammable foſſil nitre is no where to be found *. Here, indeed, the nitre was in an imperfect ſtate, but ſtill inflammable. There is great probability, that a real nitre may ſometimes exiſt in the bowels of the earth, ſince the alkaline baſe often appears in waters. The experiments performed on mineral waters at Paris before the Royal academy of ſciences, demonſtrate clearly the exiſtence of a nitrous ſalt †.

Since this acid ſeems of ſo volatile a nature, let us try if hard water diſtilled gives any ſign of containing an acid.

Exp. 119. I diſtilled ſome hard water. The diſtilled water ſhewed no effervеſcence with alkaline ſalts, but turned the ſyrup of violets into a light red. Common ſoft water had no ſuch effect. Here, then, we diſcover an aceſcent quality in the ſteams of hard water, that can riſe only from an acid exiſting in that water; and as the water gives no marks of acidity, we muſt conclude, that, by adhering to an abſorbent baſe, it is converted to a neutral ſalt.

There cannot be a ſtronger proof that waters owe their hardneſs to ſuch a ſalt, than to ſhew that ſimilar artificial compoſitions have this effect. Such ſalts as theſe muſt be continually produced by nature; as an acid and different abſorbent earths are almoſt every where to be found.

Exp. 120. Four grains of the earthy reſiduum of white pearl aſhes were ſaturated with the ſpirit of vitriol, and half an ounce of water

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* De element. aq. mineral. &c. par. 39.

† Vid. Du Clos.

added. Two parts of this ſaline liquor added to three of the rain-water, would not break ſoap.

Exp. 121. The ſame quantity of chalk was managed the ſame way. Two parts of this to three of rain-water made the ſoap riſe to the ſurface.

Exp. 122. Six drops of ſpirit of nitre, ſaturated wirh chalk, made ſoft water ſo hard, that it required 60 ſpoonfuls before it would break ſoap.

Exp. 123. The ſame quantity of ſpirit of ſea ſalt ſaturated the ſame way, required 80 ſpoonfuls.

Exp. 124. The powder which was precipitated by ol. tart. p. d. from three Engliſh pints of hard water, being ſaturated with oil of vitriol, made the ſame quantity of ſoft water nearly as hard as what the former had been; for equal parts of this artificial hard water mixed with ſoft, diſſolved ſoap, though with ſome difficulty. The quantity of acid was 66 drops. There was a great part of this earthy ſubſtance, which the acid could not diſſolve.

Theſe different experiments ſeem to have clearly made out, that the hardneſs in this water is owing to an imperfect ſalt, compounded of the nitrous acid and an abſorbent baſe. It is probable, that moſt waters, excepting the mineral, owe their hardneſs to the ſame cauſe; eſpecially when we conſider that it is obſerved of them all that they give fleſh boiled in them a red colour. I have examined many different hard waters in different parts of the country, and have always diſcovered the acid to be nitrous, but the baſe only abſorbent, and never calcarious but in the foregoing. Thus we ſee the very ingenious Dr. Stephen Hales has come near the true cauſe, when he ſays, "That the hardneſs of many waters, and "their curdling and coagulating of ſoap, may "be, in a good meaſure, owing to the tarta-"rine quality with which they are impreg-"nated." By the tartar of waters, the Doctor, I ſuppoſe, means that ſtony part which is depoſited on the inſide of veſſels. This is, indeed, one part of the compoſition of theſe hardening particles: but this alone we found to have no ſuch effect; it is to the acid, and theſe abſorbent earthy particles, compounded into a neutral ſalt, that we have, by experiment, diſcovered this hardneſs to be owing.

Having now examined the effects of alkaline ſalts on natural hard waters, and, by that means, made a diſcovery of their nature, let us examine the effects of theſe ſalts on lime-water; for that, perhaps, may give us ſome light into the nature of lime.

Exp. 125. Into 6 gills of lime-water, ſtrained from the cruſts, I poured a ſolution of alkaline ſalt, till no more lacteſcency appeared. The quantity of dry alkaline ſalt required, was 8 gr. During the addition of the ſolution, there appeared a great inteſtine motion, ſuch as happened in the hard water; the milky clouds moved ſwiftly through the fluid; but I perceived no air-bubbles. It is not, however, in the appearance of air-bubbles, but in the inteſtine motion, that an effervеſcence conſiſts. The lacteſcent mixture, having ſtood all night, was clear next morning, and had depoſited a white powder. The whole being ſhaked together, was ſtrained through brown paper, and left an impalpable powder, weighing 4 gr. when dried. The remaining liquor did not efferveſce with acids; and when evaporated, left 11 gr. of a light brown powder.

The former powder did not liquify in the air, nor diſſolve in the mouth like a ſaline ſubſtance. It taſted as if a little ſea ſalt had been mixed with it. It effervesſced ſtrongly with ſpirit of vitriol; and emitted a ſharp acrid ſmell, when oil of vitriol was mixed with it. Being calcined, and mixed with water, it afforded a good lime-water.

The latter powder had a pungent ſaline taſte, turned moiſt by keeping, was not altogether diſſolvable in water, did not afford a lime-water before calcination, and effervesſced ſtrongly with vinegar. Three grains of the powder mixed with 1½ oz. of water, made it turbid, and the powder fell directly to the bottom. Some of the water, when ſtrained, effervesſced with ſpirit of vitriol. This ſhews, that part of the powder is diſſolvable. With the remaining unſtrained liquor, ſpirit of vitriol made a ſtrong effervesſcence; there remained half a grain of powder that was indiſſolvable by the ſpirit. Some of the powder being calcined for two hours, I got an acrid pungent ſubſtance, which taſted exactly like a lye of ſalts and lime, and had the ſame taſte when diſſolved in water.

Exp. 126. I tried this experiment again, to be aſſured of the facts. The ſame quantity of ſtrained lime-water was uſed, and the ſame quantity of the ſame ſolution. The reſiduum left in the paper weighed 6 gr. and that got by evaporation from the liquor weighed 10 gr. The latter was now ſo cauſtic, that it bliſtered the tongue on touching it; was almoſt indiſſolvable in water; and had the taſte of the cauſtic liquor drawn from lime and ſalts. The former, when calcined, taſted juſt like quick-lime; made a hiſſing noiſe when water was poured on it; and gave good lime-water.

It is difficult to account for theſe phænomena: we ſhall, however, make ſome attempt towards it, and carry, when it is poſſible, experiment along with us.

It is ſufficiently made out by Dr. Aſton's accurate experiments, that quick-lime conſiſts of a diſſolvable and an indiſſolvable part. The former appears to be about the third part of the whole. The latter is reducible, by fire, into the former; and therefore we ſhall treat only of the diſſolvable part. There are many diſputes concerning its nature. That it ſhould be ſo, is not at all ſurprizing, conſidering how late chymiſts were in examining this ſubſtance, and how few experiments have yet been tried with regard to it.

The firſt diſpute is, whether it ought to be called a ſalt or not? This ſeems only to concern words. If the definition of a ſalt had been firſt given, I imagine this diſpute would ſoon have been determined. If a ſalt be a ſubſtance which has a pungent taſte, and is diſſolvable in water; and I know no other definition but this, that can ſuit all ſalts; ſurely the diſſolvable part of lime has as good a title to be ranked in that claſs, as any other ſalt, as it imparts ſuch a ſenſation to the palate, and is diſſolvable in water. It is in the ſolubility itſelf, and not in the degree of it, that the nature of ſalts conſiſts. That it, afterwards, changes into cruſts, and becomes inſoluble, never can affect it in its former ſtate; becauſe it is then altered, and no more the ſame body, though reducible in part to it.

What is the nature of this ſoluble ſubſtance? is the next queſtion. Monſ. Du Fay has endeavoured, in two papers, to make out that it is, or that it contains a neutral ſalt; for he never ſays, that he extracted all the ſalt from lime that could be got. He ſeems only to have got the moſt ſoluble parts of this ſubſtance, or as Monſ. Malouin thinks, the cruſts, and to have miſtaken them for a neutral ſalt. Monſ. Malouin ſays, that the ſalt of lime is a true neutral ſalt, conſiſting of a vitriolic acid and a terreſtrial baſe. This he proves, by telling us, that, on mixing an alkaline ſalt with lime-water, he got a tartar vitriolatus; on mixing, in the ſame way, the baſe of ſea ſalt, he got Glauber's ſalt; and on adding an inflammable body, he got a ſulphur.

By the preceding experiments, it appears, that no ſuch ſalt as the tartar vitriolatus is formed from alkaline ſalts and lime-water; and therefore that gentleman muſt have been led aſtray by ſome foreign admixture in the lime he uſed. Perhaps when lime-ſtone is burnt with a coal very much impregnated with ſulphur, a ſmall quantity of the vitriolic acid may adhere to it, and produce the effects mentioned by Monſ. Malouin. Monſ. Mackay, in a ſhort but elegant treatiſe on chymiſtry, has ſhewn, by ſome ingenious experiments, that no ſuch acid can exiſt in lime; for he found, that an ad-

addition of this acid to different calcarious ſtones, changed their nature to the vitreſcible. The ſame effect happened in Exp. 22. Lime in its nature is the very oppoſite of vitreſcible bodies.

When I firſt obſerved a lacteſcency in lime-water, and a ſubſequent precipitation of a powder, and conſidered, that I had only found this effect happen in imperfect neutral ſalts, I was very much inclined, from analogy, to believe, that lime contained ſuch a neutral ſalt. The opinion was very natural. I knew of no method to procure this ſalt, by itſelf, but by diſſolving it in water. There, acids make no effervеſcence. This, however, could be no proof, that the ſalt diſſolved in it, was neutral, when I found that a grain of alkaline ſalts diſſolved in 3½ oz. of common water, made no efferveſcence with acids. I took the following method therefore to determine its nature.

Exp. 127. I ſkimmed off the ſubtileſt and lighteſt parts of lime diſſolved in water, as I had done in former experiments. Part of this was boiled in water, till it did not taſte of lime, nor made lime-water. Theſe two, and ſome of the cruſts taken from the ſame lime-water, were dried in an equal heat. Six grains of the effœte lime required 26 drops of ſpirit. ſal. marin. to ſaturate it; 6 gr. of the unboiled, 41 drops; and the ſame quantity of the cruſts, 21 drops. I added 2 tea-ſpoonfuls of water to each powder, before the acid was dropped into it. The firſt was pale, and had a dark oozy ſediment: but the ſecond was yellow, and had no ſediment. It was remarkable. that they all emitted ſtrong acid ſteams during the act of fermentation. The concluſion then from this experiment is very plain, that, allowing 18 drops for 4 gr. of the inſoluble part in the unboiled lime, which is the proportion that the boiled effœte calx took, the 2 remaining ſoluble grains muſt have conſumed 23 drops of the acid; a quantity twice and a half more than the inſoluble part required. The ſoluble part then is ſo far from being a neutral ſalt, that it becomes, by the action of the fire, betwixt two and three times more antacid than the inſoluble part is. The accurate Dr. Alſton has ſhewn, that the cruſts weigh double of the lime diſſolved; and that they get this additional weight from earth, or perhaps ſomewhat elſe, attracted from the water. Twelve grains of cruſts contain ſix grains of lime; and therefore the antacid power of the ſoluble part in theſe cruſts continues the ſame, though it is now changed from a ſaline to a terreſtrial ſubſtance. The cruſts calcined in the fire are burnt to quick-lime, and afford a lime-water. Six grains of this to quick-lime required 26 drops of the ſame acid to ſaturate it. The cruſts are found to contain only the ninth part of water; allowing then for the ninth part of water diſpelled, the fire by calcination increaſed the alkaline quality of the whole cruſts about a ninth part. But if we conſider what a ſmall proportion of theſe calcined cruſts are ſoluble in water, we muſt allow, that the ſoluble ſaline part of theſe cruſts have their alkaline quality increaſed in a much greater proportion. Theſe experiments ſhew evidently the nature of this ſoluble ſalt of lime. I would gladly chuſe to have more data before I proceed to determine how it becomes inſoluble again; yet there is no harm in attempting a little theory on the data we have, eſpecially as we will be ſupported by the preceding experiments.

The whole contents got by Exp. 125. & 126. from 8 gr. of ſalt and 6 gills of lime-water, were 15 or 16 gr. In the quantity of lime-water uſed in theſe experiments, there are betwixt 4 or 5 gr. of ſoluble lime; which, with the 8 of alkaline ſalt, and 3 more coming partly from the air, juſt make out the 15 gr. Whence then comes the precipitated powder? Is it from the lime, or from the alkaline ſalts? There is a quality in this precipitated powder, which will help us in this queſtion. I found in the courſe of theſe experiments, that the powder precipitated, in boiling, from the pearl ſalts, or, in other words, their earthy baſe, was not a calcarious earth, or could not be turned to quick-lime. The powder precipitated in the foregoing experiments afforded me, at three different trials, lime-water. Hence a plain, and, I think, an undoubted concluſion ariſes, that the precipitation comes from the ſaline part of the lime, and conſiſts moſtly of it.

It appears by one of theſe experiments, N°. 126. that the powder precipitated is more than the quantity of ſoluble lime in the lime-water. This appears yet ſtronger from the following.

Exp. 128. Six drachms of quick-lime were mixed with eight Engliſh pints of water. The lime was well dried in a hot fire. When the lime-water was ſufficiently ſtrong, it was ſtrained off. From this lime-water I precipitated, by the means of alkaline ſalts, 42 gr. of a powder; while the lime, dried as it had been before, and weighed, had loſt only 24 gr.

To four pints of lime-water made with lime of another kind, I added 20 gr. of ſalt of wormwood. The powder precipitated, weighed 19 gr. when gently dried; when kept nearer the fire, it weighed but 8 gr. After it had been kept two hours in a ſtrong fire, it weighed but 4 gr. and was then quick-lime. The liquor, when evaporated, gave 19 gr. of an undiſſolvable powder; five or ſix of which muſt have ariſen from the earth of the water. Theſe experiments ſhew us, that the alkaline ſalts loſe ſomething, and that the lime gains ſomething; and that the ſoluble lime has become inſoluble by this addition. If this additional ſubſtance is again diſpelled by the fire, the inſoluble lime becomes ſoluble again. But what this additional ſubſtance is, whether air, an acid, or whatever other principle it is which makes part of the alkaline ſalts, I leave to the determination of experiment. It is probably air, as no air ariſes when alkaline ſalts are added to lime-water, although there is a great inteſtine motion. It does not appear to be an alkaline body; for alkaline ſalts turn more ſo by loſing it, as appears by

Exp. 129. Four grains of this cauſtic ſalt deſtroyed 16 gutts of ſpirit of nitre; but 4 gr. of plain alkaline ſalts deſtroyed only 12 gutts. Hence it appears, that the ſubſtance attracted from the alkaline ſalts by the lime is not alkaline. We have already found likewiſe, that the lime by its addition becomes leſs alkaline,

kaline, in proportion to its bulk, than what it was before.

As there are middle natures which ſeem to join the oppoſite parts of the creation, the terreſtrial and aquatic, the beaſts and birds, the fiſhes and birds, the vegetable and the animal, the mineral and the earthy; lime ſeems to me to be a ſubſtance deſigned by the Author of All to connect the ſalts and earths, two ſubſtances that differ widely from one another. It ſometimes exiſts in the one ſhape, and ſometimes in the other. By fire it becomes ſoluble in water, but not in a great degree: by the contact and influence of the air, it becomes an inſoluble earth; ſtill however not ſo much ſo, but that it may again be reduced, by a certain degree of heat, to its ſoluble ſaline ſtate. Thus much I thought was due to a ſubſtance of ſuch general uſe in the bleachfield, and whoſe nature and compoſition was ſo little underſtood.

Having once eſtabliſhed the cauſe of hard waters, we are at liberty to uſe the analytic method, and account, from that cauſe, for their different effects. With regard to bleaching, they are of the worſt conſequence. Soap curdled by hard water, has not its natural effects, as the oil and the ſalts are ſeparated from one another. The ſame effects will happen in the bleachfield, when the linen is waſhed with ſoap. In this caſe, the latent oils and dirt will not be looſened by the ſoapy menſtruum. This is the reaſon that hard water will not waſh the dirt out of foul linen. But when the hard water was ſoftened by the alkaline ſalts, it waſhed as well as the ſofteſt water.

Again, whenever hard water is mixed with the lye, it muſt turn immediately thick. This diſadvantage can be cured, by allowing the lye to ſtand for ſome time, and drawing off the clear liquor. But there is another which cannot: the acid in the hard water joins the alkaline ſalts in the lye, reduces them to a neutral ſtate, and conſequently renders them of no effect in bleaching.

But theſe are not the only diſadvantages of hard water in the bleachfield. Theſe ſalts, thrown on the linen along with the water, muſt penetrate wherever the water goes. The ſun will ſoon volatilize the acid part; but the earthy will be left in the ſubſtance of the linen, and render it hard and huſky. Nothing but an acid can take that earth out, by reducing it again to a ſaline ſtate. Hence, if more earthy particles are depoſited by the watering, than what are carried off by the ſouring, the cloth muſt not only turn hard, but muſt be tore into holes, and rendered uſeleſs. In this way I imagine it hardens pot-herbs which are boiled in it. The more of theſe ſaline particles are in the water, the more cruſts will be formed in the veſſels in which it is boiled. Hence we find, that all hard waters depoſit much tartarine ſubſtance, while no ſoft water is found to have any ſuch effect. The Comb water, as mentioned by Dr. Hales, is obſerved to be ſofter, and to waſh linen with a leſs quantity of ſoap, than the Thames water; while it left no incruſtations in the coffee-houſe boiler, that had been in conſtant uſe for fourteen years.

Bleachers know very well how to avoid hard waters of the third claſs; but having no criterion for thoſe of the ſecond, they muſt often uſe hard water without knowing it to be ſo. I have diſcovered a great degree of hardneſs in ſome of their waters. A method, then, of detecting the ſmalleſt degree, muſt be of conſiderable uſe to them. Alkaline ſalts enjoy this property, and have already been of ſervice in this way. Mr. Samuel Hart had pitched on a ſpot of ground to make a bleachfield; had examined the ſpring by the known methods; and thought it good. But on trying it by this teſt, which I had informed him of, he diſcovered a conſiderable degree of hardneſs in it, and fixed his bleachfield on another ſpot.

As I thought an examination of different ſprings, in this way, would be of uſe in ſhewing what is the proportion of hard ſprings to ſoft, I deſired that gentleman to examine a variety of them, and give me an account of his trials. As he has done it with great pains and accuracy, I ſhall give the account in his own words.

“ I here ſend you an account of the ſeveral
“ trials I have made of waters, by a ſolution
“ of ſalts. Theſe trials were generally per-
“ formed between September 10. and October
“ 15. and when the weather was dry and
“ fair.”

“ I ſhall begin with thoſe made on ſome
“ ſprings in the neighbourhood of my bleach-
“ field at Ford, viz. on the lands of Vo-
“ grie, Cheſterhall, and Crichton. The firſt
“ ſpring tried was on Vogrie, commonly
“ called

“ called Haly-well; which, on mixing the ſalts “ became immediately turbid, and of a bluiſh “ colour; and, after fifteen minutes ſtanding, “ ſuſpended many white, fleecy particles, “ which in about three hours were altogether “ precipitated, and the water remained “ pure as at firſt. Theſe particles were more “ copious and ponderous than what I have “ obſerved from any other water. This I “ learned from the great quantity depoſited, “ and the quick precipitation. I obſerved all “ around this ſpring great quantities of lime-“ ſtone, through which I conceived it paſſed, “ and to which I aſcribe its hardneſs. I have “ been further confirmed in this, by every trial “ made of water from limeſtone; having con-“ ſtantly the ſame appearance with this now “ mentioned, in a greater or leſſer degree. “ The following experiment will afford a fur-“ ther proof. Obſerving near this a great con-“ fluence of ſprings, which proceeded alſo from “ lime-ſtone, and emptied themſelves into the “ Tyne, near the ſame ſpot, and knowing the “ general opinion, that river-water is ſoft, “ I determined to try, how far theſe ſprings “ affected it with their quality, and found the “ river-water here partook of it in a conſi-“ derable degree. At firſt, on the mixture of “ the ſalts, it remained pure, and continued “ ſo for about fifteen minutes, at which time “ it ſuſpended a blue cloudy ſubſtance in the “ middle of the glaſs. I had not leiſure to “ attend its further progreſs; but no doubt it “ would have depoſited a white powder like “ the other, though not ſo copious.

"As I had a deſign of fixing my bleachfield "here, induced by the largeneſs of the ſpring, "I was led to a further trial, by filtering the "ſpring through the ſoil, which is a light "brown earth, with a ſmall mixture of ſand, "in hopes of ſoftening it thereby. For which "purpoſe I cauſed two pits to be dug, about "three and a half feet deep, turning the "ſpring into the upper one; which, when "filled, after ſome hours filtered through the "ſoil to the lower pit: from which, two days "after, when the water had ſettled, and "become pure, I made trial with the ſalts; "and was ſurprized to ſee it more turbid "than when taken immediately from the ſpring. "I made repeated trials, and found it invariably "the ſame. I imagine it had acquired an "accretion of ſalts by paſſing through the "ſoil; but this I leave to you to determine. "I made trial of five other ſprings on Vogrie; "two of which proved like this, but "not altogether ſo hard. The other three, "which roſe on the high ground through a "bed of white ſand, is a ſtrong run of water, "known by the name of the Carſe well. This "is the ſpring I have choſen to ſupply my "bleachfield. After mixing the ſalts with "ſome of this water, it continued quite pure "for three days, the time I kept it in the "glaſs: and as from this favourable appearance "I had reaſon to think the ſpring very "ſoft, I determined, from other corroborating "proofs, to be farther aſſured; for which purpoſe "I made two comparative trials with

" water from another ſpring, which I had " found very ſoft, but not altogether ſo much " as this, and might be reckoned next in " quality. This water had remained pure for " above two hours, and then diſcovered a very " ſmall, and rare light cloud, ſcarce percepti- " ble by the eye, and that only in a certain " light. I took two wine-glaſſes of each wa- " ter; in each I put ſome hard white ſoap, " pared down, to be diſſolved; in the other " two, ſome galls. I perceived, that the ſoap " in the Carſe well water more readily and " equally incorporated, and the gall produced " more ſpeedily a ſtronger tincture than in " the other water. This proof determined " me.

" Three ſprings I tried on Crichton ground " were of the ſame nature with Haly well, " but were longer in diſcolouring, and depoſited " a much ſmaller quantity of white powder.

" Of four ſprings I tried on Cheſter-hall, " I found three quite ſoft: the other had ſome " ſmall degree of hardneſs; it continued pure " for about an hour and an half; when it ſuſ- " pended, about half an inch from the ſur- " face, a light and rare blue cloud. In brief, " I made trial of about twenty other ſprings, " and found always the ſmalleſt degree of hard- " neſs diſcoverable by the ſalts. The ſeveral " waters I tried, may be ranged into three " claſſes, viz. ſuch as continued pure; ſuch as " ſuſpended only a light cloud, after ſtanding " ſome hours, and depoſited very little pow- " der; and laſtly, ſuch as became immediately " turbid, and diffuſed their foulneſs through

" all the water; which commonly appeared
" of a milky colour. I always obſerved thoſe
" ſprings that proceeded from ſand and gravel
" to be ſoft, as thoſe from lime-ſtone to be
" hard. I ſhall only communicate one further
" trial, with which I ſhall conclude, and which I
" only acquaint you with, as being ſimilar to the
" trial made at Vogrie, of filtering water.
" On ſeeing a pool of ſtanding water which
" had filtered from the Tyne near Niſbet,
" through much the ſame ſtratum as at Vogrie,
" I made trial with the ſalts; and found, although
" I had taken it up, quite pure, that
" it became immediately very turbid, to much
" the ſame degree with that at Vogrie. From
" whence it may be obſerved, that though
" hard water, when percolated through ſand
" or gravel, may be conſiderably corrected
" and ſoftened; yet that every ſoil, through
" which water can penetrate, will not produce
" this effect, is evident from the two former
" recited experiments. It will then follow,
" that ſand or gravel is the only ſoil we know
" of that is proper to ſoften water by filtering.
" I take this occaſion to return you my
" hearty thanks for the favour you have done
" me, in communicating the method of proving
" water by ſalts; and am," &c.

Salton, Dec. 26. 1753.

Exp. 130. To try what effect hard waters, ſoftened in the preceding way, would have on vegetables, I boiled ſome peaſe in ſoft water, ſome in hard water, ſome in the hard water ſoftened with alkaline ſalts, and ſome in lime-water. Whenever the peaſe became ſoft in the ſoft water, the whole was removed from the fire. The peaſe in the hard waters, and in the lime-water, were too hard to be eat; but thoſe in the hard water ſoftened, were ſo ſoft, that very few of the peaſe remained entire. Thus tea, malt, &c. muſt yield a much ſtronger tincture to ſoftened, than they do to hard water. I poured equal quantities of hard water, and hard water ſoftened, on equal quantities of Bohea tea. The tea was ſtronger with the latter water than with the former.

The antiſeptic quality of hard waters diſcovered by Exp. 86. is not taken notice of, ſo far as I remember, by any author except Celſus. He has theſe words: "Aqua dura, i. e. "ea quæ tardè putreſcit." According to him, this antiſeptic quality is the characteriſtical mark of hard waters. Let us try ſome experiments with regard to this quality of hard waters.

Exp. 131. Nov. 12. An ounce and an half of beef was put into a glaſs with 6 oz. of ſoft water. The ſame quantity of beef was put into another glaſs with the ſame quantity of hard water. The ſame was done in two other glaſſes, with the ſame quantity of fiſh. Nov. 22. The fiſh and fleſh in the ſoft waters were putrified, but the others were quite ſound. Nov. 27. A piece of each of the latter being roaſted on a fork, were firm and good, but ſomewhat dry. Dec. 2. Both ſpoiled. Hence we diſcover, that hard waters have a ſtrong power of preſerving bodies, and may be made uſe of in this way with ſucceſs. Waters three times harder than this, as I have diſcovered thoſe of Newcaſtle to be, muſt have a very ſtrong antiſeptic power.

To diſcover the comparative antiſeptic qualities of ſeveral ſubſtances, I made the following trial.

Exp. 132. Dec. 1. One ounce of beef was put into a glaſs containing eight ounces of ſoft water. I ſhall call this glaſs N° 1. N° 2. contained the ſame, with the addition of a ſcruple of common ſea ſalt. N° 3. contained the ſame, with the addition of 2 dr. of the ſame ſea ſalt. N° 4. contained the ſame, with the addition of a ſcruple of the cryſtals of pure ſea ſalt. N° 5. with the addition of 2 dr. of the ſame ſalt. N° 6. contained the ſame quantity of beef, with the ſame quantity of hard water. N° 7. the ſame quantity of beef, and freſh-made lime-water. N° 8. the ſame quantity of beef and tar-water. Dec. 8. N° 4. & 5. began to ſmell putrid, and the latter not ſo ſtrong as the former. N° 2. juſt begins to have a little ſmell, but not near ſo much as any of the two former. Dec. 16. N° 1. & 3. begin to ſmell. N° 2. very putrid. N° 7. is likewiſe very putrid; and ſtill ſo hard, that it curdled ſoap. N° 6. quite freſh, with a quantity of air-bubbles on the ſurface of the water; which ſhews a beginning change. Dec. 26. N° 6. ſmells putrid. N° 8. continues ſtill ſound.

From this experiment the following concluſions ariſe. 1ſt, This hard water appears to be a ſtronger antiſeptic than lime water *, but not ſo

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* There is a difference in opinion with regard to the antiſeptic effects of this ſoluble part of lime,

ſo ſtrong as tar-water. 2dly, Two drachms of pure ſea ſalt, diſſolved in 8 oz. of ſoft water, increaſed conſiderably in ſeptic power. 3dly, Two drops of common ſalt preſerved the fleſh twice as long as the ſame quantity of pure ſalt. This muſt have been owing to the mixture of the bittern with the former; and ſhews, that theſe two ſalts have very different effects.

We could eaſily account for all the bad effects of hard water on the human body; and ſhew, that, by the ſeparation of the acid from the terreſtrial baſe, which muſt happen in the body, ſeveral diſeaſes muſt ariſe; ſuch as, the ſtone and gravel, rheumatiſm, cholics, gout, and many others; but this is not the proper place. Theſe unhealthful effects of hard water may be eaſily prevented, by mixing alkaline ſalts with it. The hard water I have uſed in theſe experiments, takes about 1 dr. to one Engliſh pint: A very ſmall quantity to produce ſo excellent an effect. The milky water muſt be allowed to ſtand till it becomes clear, before it is uſed for drink.

To

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lime, betwixt two gentlemen, to whom the world is much indebted for many ingenious and accurate experiments; I mean Dr. Aſton and Dr. Pringle. The former ſays, that the ſoluble part of lime, or lime-water, is antiſeptic; the latter, that it is not. When ſuch ingenious gentlemen, who reaſon and form concluſions from experiment alone, differ in opinion, it muſt be from their viewing things in different circumſtances and ſituations. I am always apt to conclude in ſuch caſes, that both opinions are, To diſcover whether the effect of hardening vegetables depended on the acid, or on the earthy particles left in the ſubſtance, I tried the following experiment:

Exp. 133. Four different parcels of green peaſe were boiled, for the ſame time, in the ſame degree of heat, in four different waters; viz. ſoft water; hard water; artificial hard water, made with the abſorbent baſe of the hard water, and the oil of vitriol; and ſome ſoft water, with as many drops of the ſpirit of nitre in it as I thought was equal to the acid of the hard water. When the peaſe of the ſoft water were enough boiled for eating, I took out the whole. The peaſe in the hard water were ſo hard, that they could not be eaten; and at the ſame time not ſo green as thoſe in the ſoft water. Thoſe in the artificial hard water were like the former. Thoſe in the water with the nitrous acid, were lighter-coloured, and ſofter than the reſt; their ſkins were moſtly broke. The earth was found before

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are, in ſome meaſure, true. It is then worth our labour to diſcover by experiment, what difference in the circumſtances of theſe experiments gave riſe to ſuch difference in their concluſions. I am the more particularly called upon to give my opinion in this queſtion, as two letters of mine, which were not deſigned to be made public, have been, by a miſtake, publiſhed in the Philoſophical Tranſactions.

Exp. 1. Dec. 6. I put two haddocks in an earthen pot, which held $3\frac{1}{2}$ Engliſh pints, and filled fore not to harden water, and the acid is now. Hence it muſt ariſe from the ſaline particles entering compounded, and the acid leaving the earthy behind; which, from the volability of the former, muſt ſoon happen. Hard water, though it does not make vegetables greener, as is generally thought; yet as it keeps them longer hard, it keeps them longer green.

This method which we have diſcovered * of ſoftening hard waters, is eaſy, expeditious, and cheap; qualities abſolutely neceſſary to render it uſeful to the public. It is eaſy, as the moſt ignorant can do it; expeditious, as it becomes fit for all family-uſes immediately, and for drinking in half an hour; and cheap, as the material coſts but a mere trifle; nay may be prepared by any perſon. By this change, the hard water not only becomes fit for all the common uſes of life, but as beneficial as it was before hurtful to the health of man. Lord Verulam had ſo high an opinion of the ſalutary effects of nitre, that, as we are told, he uſed to

* See Note at page 196.

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filled it with lime-water. One lb. of beef was put in another pot of the ſame bigneſs, and filled with lime-water. After they had ſtood, well corked, eighteen days, the former was quite ſweet, and ſmelt like good lime-water; but the latter had a putrified ſmell, though not very ſtrong. One of the fiſh was partly boiled, and partly dreſſed on the grid-iron; and it eat both ways very well, though a little ſoft, and retaining ſomewhat of the taſte of lime-water. The fleſh was a little tainted, and of a whitiſh colour, to mix it with all the water he drank. Hard water, when corrected by alkaline ſalts, turns into ſoft water impregnated with nitre. I may venture to affirm, that no other material can ever be found capable of ſoftening hard water: and though one was diſcovered endued with the ſame property, it could not be of the uſe to mankind, as there is none, alkaline ſalts excepted, to be had every where. A particular ſubſtance or plant was only to be found in particular places, but this material is to be got wherever plants grow. So kind is the general Parent of Nature, that he has provided a remedy, every where to be found, for ſo common an evil; but at the ſame time, has left the diſcovery to our own induſtry.

How much we ſtood in need of ſuch a diſcovery, moſt great towns, eſpecially thoſe on the ſea-coaſt, nay the greateſt part of ſome counties, can teſtify. Newcaſtle is a remarkable inſtance of this diſtreſs. In all the pants or pipes there, two excepted, the water is hard; and

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colour, when prepared in the ſame way. Freſh lime-water was put on both, the former being poured off. When they had ſtood four weeks longer, the fiſh was quite freſh, and appeared ſomewhat ſwelled; but the fleſh was very putrid. When the fiſh was put into boiling water, it diſſolved immediately into a jelly. Lime-water appears, then, to deſtroy the cohering principle in fiſh.

Exp. 2. March 26. I hung about 3 oz. of fleſh and a ſmall haddock in the open air in the kitchen;

and to ſuch a degree, that it is three times more ſo than the hard water which I have examined. The nitrous acid, joined to an abſorbent baſe, is the cauſe. The precipitation from theſe waters, by the means of alkaline ſalts, was in ſo great plenty, that the fourth part of the glaſs was covered with it, and amazed not a little thoſe who made uſe of the water. There the old and infirm complain, that theſe hard waters give them a ſourneſs of the ſtomach, and cholics.

As the ſtrength of different alkaline ſalts differ, and as ſome hard waters are much harder than others, nay the ſame water harder in dry than in wet weather, ſome eaſy and certain general rule of ſoftening all hard waters is neceſſary; the following appears to me the beſt. Let a certain quantity of alkaline ſalt be diſſolved in a certain quantity of ſoft water. Into a certain quantity of hard water in a glaſs, pour in the ſolution gradually, ſo long as the milky

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kitchen; put the ſame quantities of theſe two ſubſtances in two different pots filled with common water, ordering the water to be changed every day; and the ſame quantities of the ſame ſubſtances into two pots, ſuch as I mentioned in the former experiment. April 2. The fiſh and fleſh in the air were dried; the fiſh had no bad ſmell, but the fleſh was tainted: the fiſh and fleſh in common water ſmelt ſtrong: the fiſh in the lime-water was ſweet, but the fleſh ſmelt as ſtrong as that in the common water.

Exp.

milky colour is on the increaſe. When that is at the height, let the water ſtand till it becomes pellucid. Try it again with a few drops of the ſolution; if no whiteneſs ariſes in the water, it is then ſoft; if there does, go on drop by drop until no more white clouds ariſe. By this means it is known what quantity of ſalts is neceſſary to ſoften that quantity of water; and, conſequently, how much any given quantity of water will require.

Quær. 1. Is not hard water more nouriſhing for vegetables than ſoft water? I imagine, that the ſalt of vegetables enters their veſſels in ſuch a form as this ſalt of hard waters. The ſalt likewiſe ſeems to be of the nitrous kind; which we think the nouriſhment of plants. As this quære is oppoſite to the general opinion, (for no gardener will make uſe of hard water, if he can ſhun it,) I watered ſome plants with it, and thought that they grew better than thoſe which were watered with ſoft water.

Quær.

Exp. 3. May 18. Into four different glaſſes, each of which held 3 gills of lime-water, I put four different ſubſtances; into the firſt 1 oz. of beef; into the ſecond the ſame of lamb; into the third the ſame of mutton; into the fourth the ſame of whiting; and corked them. 26. The glaſs containing the lamb ſtunk much; the beef and mutton were a little corrupted; but the fiſh quite ſound. June 2. The fiſh was ſtill ſweet, but all the fleſh ſmelt very ſtrong: the lime-water in which the beef was, appeared of a high red colour; that in which the mutton was, appeared leſs red; that with the

Quær. 2. May not hard water be proper for ſome particular conſtitutions, and for ſome particular diſeaſes, ſuch as putrid fevers, &c.? The antiſeptic quality of theſe waters would ſeem to be uſeful to putreſcent habits.

Quær. 3. Do theſe hard waters ſupply the air with a nitrous acid? We have diſcovered by theſe experiments, that the nitrous acid of this water is eaſily ſeparated, by a boiling heat, from its abſorbent baſe; and that it ariſes even by a gentle diſtillation. We find likewiſe, that all hard waters depoſit more or leſs of an abſorbent earth. Hence we may reaſonably conclude, that there is a real nitrous acid, diſtinct from the vitriolic acid, communicated by theſe hard waters, to the air; and that from the former, and not from the latter, as chymiſts have imagined, nitre is generated. This is fur-

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lamb was but gently tinctured; that with the fiſh was ſtill white. The lamb ſeemed moſt putrid. June 7. Fiſh ſound. 26. Fiſh was putrid. Aug. 6. The fiſh ſmelt more offenſively than any of the former.

Would not any one be apt to conclude from theſe three experiments, that lime-water preſerved fiſh, and not fleſh? I did ſo; but was ſoon convinced of my error by the following experiment.

Exp. 4. May 19. Into an earthen pot, holding 3½ Engliſh pints of common water, I put 1½ oz. of mutton; into another holding the ſame quantity of lime-water, I put the ſame quantity of mutton. 26. The mutton in com-

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further confirmed by an obſervation of the learned Dr. Plummer, who ſays, that he has oftener obſerved nitre produced or regenerated, than vitriolated tartar, from an alkaline lixive long expoſed to the air.

Quær. 4. Is not hard water more proper to be carried to ſea than ſoft water, as it appears to reſiſt putrefaction very powerfully?

Quær. 5. Is not the cauſe of hard and petrifying waters the ſame? and do not they differ only in degree? When the ſaline ſubſtance impregnates the water very ſtrongly, the earth depoſited in the interſtices of any ſubſtance, muſt be continually on the increaſe, till at laſt the ſubſtance becomes a ſtone. This I imagine is the way that all petrifying waters act, and accounts very naturally for their effects.

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mon water was putrid, but that in the lime-water was not. June 7. Fleſh in the lime-water ſtill ſweet. 26. Still ſound. Aug. 6. Was a little putrid.

It appears then, from theſe experiments, that lime-water is antiſeptic, with regard to fleſh, when uſed in a certain quantity, and when the pieces of fleſh are ſo ſmall that the lime-water can eaſily penetrate them; that lime-water is antiſeptic, with regard to fiſh, in a greater degree, probably becauſe it more eaſily penetrates fiſh from its leſs firm texture; and that the difference of theſe two ingenious gentlemen's concluſions aroſe, probably, from their uſing, in their experiments, different quantities of fleſh and lime-water.

Quær. 6. Do not the brewers, in great cities, who generally make uſe of hard water, loſe a very great part of the ſubſtance of their malt, as we have found hard water very unfit for drawing a tincture from any vegetable? Will not hard water, ſoftened in this way, make ale of a much greater ſtrength from the ſame quantity of malt? and what effect will nitre have on ale?

Quær. 7. Do hard waters contribute to ſterility, as Hippocrates aſſerts?

Quær. 8. Muſt not hard waters have in general a very bad effect on digeſtion, as they tend to keep all bodies in their natural ſound ſtate?

Quær. 9. How happens it that Briſtol water is reckoned ſo exceedingly ſoft, inſomuch that

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(Note referred to at p. 190.)

* I have diſcovered, ſince theſe papers were in the preſs, that Dr. Shaw, in his chymical diſcourſes, has given an imperfect hint of the quality of alkaline ſalts. He ſays, that hard water becomes ſofter by an addition of alkaline ſalts. I call this hint imperfect, becauſe hard waters may be made ſofter, and yet continue hard, as they admit of various degrees of hardneſs. The foregoing experiments ſhew, that all kinds of hard waters are altogether ſoftened by alkaline ſalts. Nor does the Doctor inform us of the manner of doing it, or reaſons on which it depends, or qualities of the water after it is ſoftened.

that it is thought to come from chalk, when it is really a hard water? What acid does it contain? Are not its effects in conſumptive hectic caſes owing to this imperfect neutral ſalt?

Quær. 10. Is not the effect of hard water in turning pewter black, owing to a ſolution of the metal by the acid?

Quær. 11. Are all waters hard which lie at a conſiderable depth below the ſurface of the earth? and is it not neceſſary that theſe ſhould have ſome particles in their compoſition of an antiſeptic nature, to reſiſt the effects of heat and ſtagnation, to which they are liable?

SECT. III.

The effects of ſteel and coal waters on cloth, and the cure.

HARDNESS is not the only pernicious quality in water which the bleacher has to ſhun. All impregnations with bodies ſuſpended in that fluid, whether they are earthy, ſaline, or metallic, retard, nay often entirely ſtop the whitening of cloth. There are two ſpecies of waters particularly deſtructive to this art, I mean vitriolic or chalybeate waters, and coal waters. As theſe are very common to this country, the bleacher ought to be more upon his guard againſt them. It therefore becomes neceſſary for him to be able to diſtinguiſh them from other waters, and to remove their bad effects when they happen to be uſed.

All ſteel waters, whether the iron be diſſolved by an acid or not, depoſit a red ſubſtance, called ochre. This is to be obſerved in the channel where theſe waters run. It is moſtly compoſed of the particles of iron precipitated to the bottom, with a ſmall addition of whatever ſaline ſubſtance exiſts in the water. Theſe particles are depoſited, continually, on the ſurface of the cloth, when watered with a chalybeate water, and effectually ſtop all further progreſs in whiteneſs. This happened to a poor woman, who watered ſome webs ſhe was bleaching from a ſpring near her own houſe. To her great ſurpriſe they turned redder and redder every day. Not being able to account for this effect in a natural way, or to remove that colour, ſhe imputed it to witchcraft, blamed the neighbour ſhe hated moſt, and ſold them for a trifle. That water was afterwards diſcovered to be a mineral ſpring.

Had ſhe conſulted a chymiſt, he would have ſhewn her a method of diſſolving the charm. Water, with the addition of a ſmall proportion of oil of vitriol, would have carried off the ochrey matter. I watered ſome white linen with the Hartfield ſpaw water, till it had acquired a pretty ſtrong red colour. This linen ſteeped in water gently acidulated with vitriol, in a few hours, come out white again. I am not ſure, however, whether all ochres can be diſſolved by acids. I have tried ſome which were not. Againſt theſe I know no remedy.

It is therefore of great conſequence to the bleacher, that he ſhould be able to diſtinguiſh theſe waters, when he meets them, from others, in order to ſhun them in the ſituation of his bleachfield. The characteriſtical mark of theſe waters, is, That they turn purple or black with galls, green tea, or the leaves or bark of the oak. If this effect happens, on the mixture of theſe bodies, the water is improper for bleaching.

There is an ochrey ſubſtance, like the former in appearance, which has not yet, ſo far as I know, undergone any examination; I mean that of coal waters. Whenever they are uſed in the watering of cloth, they leave a yellow colour. That we may be able to remove theſe particles when lying on the ſurface of cloth, it becomes neceſſary to examine their nature, and to diſcover their proper ſolvent.

This examination will be attended with another advantage. This ochrey ſubſtance is reckoned one of the ſureſt marks of coal. But how can it be depended on, when many waters, which do not come from coal, have a like appearance, and when the diſtinguiſhing properties of their ſimilar ſubſtances are not aſcertained? A chymical examination is the only method to fix theſe. I have elſewhere examined the ochre of mineral waters, and diſcovered its properties and nature *. I ſhall endeavour, here, to do the ſame with that of coal waters. The ochre I made uſe of was taken up carefully from the channel of a coal-level, and had been kept by me near a year.

Exp. 134. The ochre of coal waters has no particular taſte, and feels in the mouth gritty, and not fat, as that of mineral waters does.

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* Eſſay on Dunſe ſpaw.

When put on a red-hot iron, it ſparkles, but emits no ſulphureous or acid ſteams.

Half a drachm of it mixed with warm water, and the liquor ſtrained and evaporated, gave a ſmall quantity of a ſaline reſiduum, which liquefied in the air, taſted ſharp, and rendered half an ounce of water reddiſh and hard. Paper dipped in this liquor, burnt like a match, and diſcovered the ſalt to be nitrous.

It effervefced with water acidulated with oil of vitriol. The liquor, with an addition of galls, turned into an ink. When thrown on melted nitre, it ſparkled, but did not deflagrate.

The magnet has no effect on it before calcination. Twenty grains, calcined for two hours in a fire, were reduced to 14, and were all attracted by the magnet.

Two drachms and a half were diſtilled, and gave me about 1½ dr. of a liquor, which turned ſyrup of violets green, effervefced with mineral and vegetable acids, and had the ſmell of ſpirit of hartſhorn.

From this experiment, then, we diſcover the nature and properties of coal ochre. We ſee that it is compounded of iron, and a neutral ſalt, like that of all hard waters. We obſerve, likewiſe, its proper ſolvent, oil of vitriol diluted with water; and that the ſame mixture which removes the ochre of mineral waters, will remove this. But what is perhaps of greater moment, its properties appear to be very different from thoſe of other ochres. If ſuch a ſubſtance was preſented to me, I think I could tell whether it came from coal or not.

SECT. IV.

Some conſiderations with regard to the further improvement of our linen manufacture.

THE demand for manufactures is in proportion to their goodneſs and cheapneſs. That country which affords the beſt, and at the loweſt prices, will find the readieſt market. To theſe two points muſt every deſigned improvement tend. For that end the foregoing experiments were calculated. I have endeavoured, by their aſſiſtance, to ſhew where the common practice was right, and where wrong; to propoſe ſome improvements in it; to introduce new materials made at home; and to ſhorten the time of ſome operations conſiderably; to explain the principles upon which the whole is conducted; and, in ſhort, to make the bleachers underſtand their art thoroughly; the only method to make them operate better and cheaper, without diminiſhing their gains.

I am very ſenſible how difficult a thing it is to alter the eſtabliſhed opinions of mankind; and how much more difficult to alter their practice. As the experiments in this diſquiſition have been many, and the reaſonings few, the author can never expect to paſs for a theoriſt: but conſidering the prejudices of mankind, the trouble of making proper trials, and the qualities requiſite for ſuch a work, their effects in the bleachfield muſt be but very ſlow. It is reaſonable they ſhould be ſo. Alterations in the common practice of the arts are too dangerous, both for the public and particulars, to be haſtily gone into. But when experience points the way, it is unpardonable to neglect its advice.

Having now ſecured the moſt important and dangerous part of our linen manufacture, let us caſt our eyes on the other branches, and conſider if there be not room likewiſe, for further improvement in theſe. Every manufacturing country ought, if poſſible, to have the materials of their manufacture produced within the country; that it may not depend upon foreigners, nay perhaps upon their rivals in trade, whether they ſhall have a manufacture or not. The Honourable Board of truſtees for fiſheries and manufactures have given all attention to this point; and, by proper regulations and premiums, have endeavoured to encourage the growth of flax at home: but all they have done has been yet attended with little ſucceſs; and I am afraid, if ſome ſpeedy aſſiſtance is not given, things will rather turn worſe than better. Complaints have been made by manufacturers, that our home flax is not ſo good as the foreign. I am of opinion, that it is more owing to our want of ſkill in watering of it, than to our ſoil, or methods of managing it there. We have all kinds of grounds, and excellent rules laid down for their culture: but the proceſs of watering ſeems not yet thoroughly underſtood; and the practice, as carried on by the commonalty all over the country, is moſt deſtructive to the flax. As it is of ſuch importance to our manufacture, and as it is a chymical operation, we think it deſerves our conſideration, in a treatiſe deſigned to improve our manufacture by the aſſiſtance of chymiſtry.

Whoever will attend to what paſſes during the ſteeping of lint in ſtanding water, and during fair weather, or will make the experiment in the houſe, muſt find it attended with the following circumſtances. On the ſecond or third day, if the weather is warm, a great many air-bubbles ariſe to the ſurface of the water, and by degrees a ſcum or pellicle gathers there, which is full of theſe air-bubbles. The water gains a ſmall degree of heat, and a corrupted ſmell. If the flax is allowed to lie too long, it turns corrupted, black, and loſes all tenacity. Theſe effects evidently ſhew, that the proceſs of ſteeping flax is the proceſs of putrefaction carried on to a certain length.

Every one knows, that the intention of ſteeping is to looſen the harl or bark of the flax from the bun or woody part of that plant; and that it is to be accompliſhed by a ſolution of the oil, or mucilaginous ſubſtance, which makes them cohere. Putrefaction is the inſtrument at preſent employed to attain that end. The inteſtine motion raiſed by it, diſunites, attenuates, and diſſolves that vegetable glue, and renders it miſcible with water. The great art is to know when that is done. If the flax is allowed to lie any longer in the water, that oil which unites the ſolid particles of the harl is diſſolved, and the fibres loſe all ſtrength.

The time which flax muſt lie in the water, is to be meaſured, then, entirely by the quickneſs or ſlowneſs of the putrefaction. As this depends on the concurrence of many circumſtances, viz. the nature of the flax, its quantity, the heat of the weather, length of the nights, nature and quantity of the water, and many others, it is impoſſible to fix a certain time. The flax, when ſufficiently watered, acquires a ſlippery oilineſs on its ſkin, owing to a ſolution of that mucilage mentioned before: but Pliny's rule is ſtill the moſt certain, "Maceratos indicio "eſt membrana laxatior, lib. 19." The flax ought therefore to be inſpected, after the fourth day, every ſix hours; and when the bun appears brittle, and the harl ſeparates from it, the flax ought to be immediately taken out. Nor ought we to wait, as is judiciouſly obſerved in the Dublin eſſays, till the ſeparation becomes too eaſy; but leave that to be completed by the dews and warmth when expoſed on the graſs. As the danger is great in allowing it to lie too long, ſo there are ſeveral bad effects ariſing from taking it out too ſoon. The black bars which run acroſs the linen, and are ſo difficult to remove in bleaching, are none of the leaſt. To whiten theſe, the reſt of the cloth is often damaged. When flax has been kept ſomewhat too long in the water, none of theſe black bars are to be ſeen. They increaſe in proportion to the deficiency or failure in that degree of putrefaction neceſſary to ſteeping. I am told by an experienced bleacher, that he prevents, in a great meaſure, theſe black bars, by ſouring the yarn after it has been boiled with aſhes.

When we once underſtand how this proceſs is carried on by nature, we will ſoon ſee what is the buſineſs of art. We muſt regulate the proceſs of putrefaction ſo that it does not meet with too great obſtacles to ſtop it, nor be allowed to go on too rapidly. The latter muſt ſeldom be the caſe in this climate; but the former often. Running water muſt appear at firſt entirely improper for ſteeping lint, as the corrupted particles are continually carried off. Springs have the ſame fault in a leſſer degree. Nothing promotes putrefaction ſo much as quietneſs and heat; nothing ſtops it more than agitation and cold. Steeping ought always then to be performed in a place as much ſheltered from the winds, and in a ſeaſon when it will have as much heat as poſſible. I would chuſe that the water ſhould not be too ſhallow, that it may not be too ſuddenly affected by the coldneſs of the night, or other changes of weather. The more uniform the heat of the water is, the more ſafe the proceſs will be. Ponds made at the ſides of lakes or of rivers, not too near their ſource, appear in general to be the moſt eligible places. If the proceſs goes on too ſlow, on account of the nature of the lint, water, or weather, chymiſtry teaches us how to quicken it. The putrid fermentation can be checked or quickened, as well as the vinous. As yeaſt increaſes the latter, ſo do all putrid bodies the former. Some putrid vegetable ſubſtance mixed with the water, would anſwer this purpoſe.

From what has been ſaid, we may eaſily account for the practice of the Dutch, who lay the dirt and mire found at the bottom of their ſteeping ponds, on the ſurface of the flax after it is laid in the water. When that corruptible matter lies there, it communicates putrefaction to the water more equally than if it lay at the bottom. We likewiſe ſee the reaſon why thoſe who underſtand the ſteeping of flax, never allow it to touch the ground: for when that happens, the flax which lies there, bearing the preſſure of all above it, putrifies ſooner and faſter than what lies above. We may likewiſe account for another fact, that flax muſt lie four or five months in moſs-water before it is ſufficiently watered. Moſs-water, ſo far from corrupting, preſerves even animal bodies from corruption. This water is too much uſed in this country, and is highly prejudicial to the flax.

But, of all waters, none ſeem ſo bad as thoſe which have a conſiderable degree of hardneſs, becauſe theſe have already ſhewn themſelves to be almoſt incorruptible. Common practice had diſcovered this without knowing the reaſon of it, and therefore hard waters are marked as improper. If they muſt be uſed, we are ordered to fill the ponds, and expoſe the water to the ſun for ſome weeks *. But it has appeared from undoubted experiments, that there are many degrees of hardneſs, which have not hitherto been diſcoverable; and that expoſition to the ſun is not a remedy againſt hard waters. We have diſcovered a criterion for the former, by which we are able to perceive the ſmalleſt degrees of hardneſs; and a cure for the latter, in caſe we are neceſſitated to uſe it. Let us then, by experiment, try the effects of hard water on flax; and ſee if theſe effects can be removed, by being ſoftened in the way I have deſcribed.

Exp.

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* Vid. Dublin Eſſays.

Exp. 135. Sept. 11. I ſteeped equal quantities of flax in three different kinds of waters, viz. hard water, the ſame ſoftened with alkaline ſalts, and ſoft water. The laſt, though it broke ſoap, and was the ſofteſt in the place where I tried this experiment, was not ſo ſoft as I could have wiſhed. On the 13th they all had a ſcum, with air-bubbles on their ſurface; but the hard water had the leaſt. On the 17th all the waters had a putrid ſmell; the hard and ſoft waters were pale-coloured, but the hard water ſoftened was of a high colour. On adding ſome alkaline ſalts to a cupful of the ſoft water, it turned almoſt as high in the colour as the former. The flax in the ſoftened water, was the only one of the three whoſe ſkin felt oily. Some of each parcel being dried, that taken out of the ſoftened water was of a higher colour than the other two, and was rather too much watered; that from the ſoft water not ſufficiently; that from hard water no better than when put in. On the 20th, the flax in the ſoft water appeared to be completely watered. On the 24th, the flax in the hard water was almoſt watered, but its ſkin did not feel ſlippery as the others had done. This experiment ſhews the bad effects of hard water in ſteeping flax, and at the ſame time how to cure theſe.

The proceſs of putrefaction, by which the preſent method of ſteeping flax is carried on, admits of too great variety with regard to weather and water, and is too dangerous to be managed with ſafety by the commonality. It would be much for our advantage, and I have often thought it poſſible to diſcover, a ſafer method than that at preſent uſed. I was inclined to think, that the addition of alkaline ſalts to the water might anſwer that purpoſe. For the qualities requiſite in ſuch a body, were to reſiſt putrefaction, and diſſolve the oil betwixt the harl and the bun; and theſe two qualities appeared to me to be inherent in theſe ſalts. As I never make any uſe of theory, but to lead me to experiment, I made the following.

Exp. 136. Sept. 26. Some flax was ſteeped in ſoft water; an equal parcel in the ſame quantity of water, with the addition of 2 dr. of pearl ſalts to each Engliſh pint and a half; another parcel in the ſame quantity of water, with 1 oz. inſtead of 2 dr. Oct. 2. The firſt parcel was ſufficiently ſteeped; the ſecond not fit for taking out; and the third ſtill further removed from that ſtate. Oct. 7. The ſecond was finiſhed; but when dried, ſeemed very brittle. The third was no better than when put in.

The next thing to the relation of ſucceſsful experiments, is the relation of unſucceſsful ones. Even theſe are attended with many advantages. However unſucceſsful the laſt has been, I do not yet deſpair of finding out ſome body which will anſwer all the ends of putrefaction without the danger of it. In the mean time, it appears highly neceſſary, that ſteeping ſhould be made a buſineſs diſtinct from the raiſing of flax. In Holland it is managed by lint-dreſſers, who buy the flax ſtanding on the ground.

I am apt to think, that the great ſtop to the progreſs of our linen manufacture lies in this very point, the ſteeping of flax. Our farmers, by the wiſe regulations of the board of Truſtees, ſeem to underſtand the culture of flax well enough; and, notwithſtanding ſome ſmall diſadvantages from the nature of our climate, would raiſe it in ſufficient quantity, and find their profit in it, if they could diſpoſe of it, before ſteeping, to a ſet of people who underſtood that proceſs. The farmer is at preſent unwilling to deal in it, becauſe, though he raiſes flax of the beſt kind, it is generally ſpoiled in the watering, and becomes of leſs value than the foreign. The ſteeping and dreſſing of flax ought, therefore, to be made a diſtinct buſineſs; and, as it is the branch of our linen manufactures leaſt underſtood, ſhould be moſt encouraged. All premiums in arts and manufactures, ought to be directed to thoſe branches which are leaſt underſtood. It would ſeem at firſt neceſſary to bring over a ſet of Dutch lint-dreſſers, by proper encouragement, and that premiums ſhould be given to thoſe lint-dreſſers who produced the greateſt quantities of the beſt dreſſed Scots lint.

From what I have ſaid on bleaching, it appears, that cloth, from its hard and firm texture, reſiſts for a long time the entrance of thoſe materials which are to whiten it. But the lint and yarn are not ſubject to this objection. Would it not, then, ſave a great deal of trouble, expence, and hazard, if theſe were bleached, at leaſt in part, before they went into the loom? I am afraid it would not be ſo eaſy to manage the lint, as it is ſo light a body: but as for the yarn, I can diſcover no material objection againſt it. One I have heard, and that is, The yarn would become too oozy. But that fault, I imagine, could be corrected by the weaving, and the gentle bleaching which would afterwards be neceſſary.

It is the opinion of all the bleachers, that the cloth of this country is of too thick a fabric, owing to the coarſeneſs of the woof. I agree with them. That ſpecies of cloth requires ſo many buckings before the ſalts can penetrate into the inner parts, that the external threads are too often deſtroyed before the internal are whitened. On the contrary, the thinneſs of the oppoſite ſpecies of cloths is more than counterbalanced by the preſervation of its fabric in the bleachfield. Beſides, the expence of bleaching thin cloth is not near ſo great as that of bleaching thick. The former retain their colour better, and appear finer at the ſame price; which will always recommend them to the merchant.

There is nothing promotes an art faſter than the communication of thoſe who practice it; nothing retards it more than a ſelfiſh ſpirit of keeping all a ſecret. It is by a gradual progreſs, where one refines upon the inventions of another, and not by the endeavours of a ſingle perſon, that arts arrive at perfection. I cannot, then, but recommend to the Honourable Board of Truſtees, a ſcheme of Mr. John Chryſtie. He not only has made many advances himſelf in this art, but is deſirous that others ſhould do the ſame. He propoſes, that every bleacher eſpecially thoſe who have got, or expect any premium from the Truſtees, ſhould annually deliver an exact account of his method of bleaching. If this propoſal took place, ſeveral faults would be obſerved and corrected; ſeveral advantages gained; the bleachers made more knowing, as one may excel in a particular branch, who is very deficient in all the reſt; a complete hiſtory of the practice made out; and the art itſelf arrive at perfection. Let thoſe who ſhelter themſelves under the appearance of ſecrets, know, that ignorance always does the ſame.

I know nothing that muſt have been of greater advantage to the linen manufacture of Ireland, than their linen-hall. The manufacturer brings his cloth there, is provided by the public with a proper apartment for his goods, and is ſure of a market in a few days. The public, having the cloth under their eye, are aſſured of its goodneſs, and proves a continual check to private frauds. The foreign merchant, knowing where he can ſupply himſelf at once, is under no neceſſity of acting by commiſſion at a diſtance, or if he ſhould come, of dealing with retailers; but reſorts to this market, and makes his bargain with the manufacturer himſelf. Theſe conſiderations make their cloth go better and cheaper to foreign markets, and are ſufficient to overpower any nation who does not follow ſuch a prudent conduct.

To you, Gentlemen, who are poſſeſſed of landed eſtates, I muſt now apply myſelf. You are, or may be, the great promoters and directors of induſtry among your tenants and dependents.

pendents. It is from you that the commonalty will take that bias of mind, which makes them uſeful or uſeleſs ſervants of the public. It is in your power, by procuring materials at the cheapeſt rates; by encouraging the induſtrious, and diſcouraging the ſlothful; by ſmall premiums to excite emulation; by taking the rents of your houſes in manufactured goods, rather than money; by inſtituting markets at proper times for the ſale of yarn; and by many other methods, to raiſe a ſpirit of labour and induſtry.

There is nothing ſeems more to be deſired, than a change in the education of the young people of both ſexes. While it continues on the preſent plan, of educating them, at a public ſchool, to reading, writing, and compting, I have no hopes of ſeeing them very induſtrious. That habit can only be got when young. By the preſent plan they are a burden on their parents till they are fully grown up, while they might be acquiring ſtrong habits of induſtry, earning their own bread, and adding to the wealth of their country. The conſequences of this education are viſible, after the men have applied to day-labour; for they know not how to turn to any account four or five hours every night during the winter, too much time to be loſt, and which might yield a conſiderable advantage, if they had been taught ſpinning, or any other ſpecies of manufacture. It is well if this turn to ſpeculative knowledge, which they have got, is attended with no worſe conſequences. It would be for the advantage of this country, nay for the real happineſs of its in-

inhabitants, that we had ſpinning miſtreſſes, as well as ſchool-maſters, in every pariſh.

Neceſſity is allowed to be the greateſt ſpur to induſtry. People work not for pleaſure, but for a livelihood. When that is eaſily procured, as in cheap years, induſtry abates; when with greater difficulty, as in dear years, induſtry increaſes, I have often thought, that thoſe ſorry cloaths, houſes, and meals, to which our commonalty has been accuſtomed, inſtead of being aſſiſtants, as they may appear at firſt ſight, were great enemies to our growing manufactures. Our people work but in proportion to their demands; and if at any time they have more money than ſupplies them, it is ſpent in drink. It is only the gentlemen who can bring about a change in theſe articles. Till I can ſee a greater degree of refinement; till I can hear that our commonalty are poſſeſſed of ſtronger deſires with regard to thoſe conveniencies of life than they are at preſent, I ſhall expect no change in their activity.

It is to the government we muſt chiefly be indebted for the progreſs of our linen manufacture. It is there alone that eaſe can be had from the duties on ſoap and aſhes, which bear hard on our manufacture. It is there alone that a conſtant market can be provided for us, by encouraging the exportation of our own, and diſcouraging that of foreign cloth; and by other methods which the wiſdom of the nation ſhall think proper. Without ſome proper and ſpeedy encouragement of this kind, our manufacture muſt ſoon decline; perhaps it does ſo at preſent. No induſtry on our ſide can poſſibly counterbalance thoſe heavy taxes which we pay on all the neceſſaries of life, and which our rivals in trade know nothing of. If we are obliged to give up the linen, we muſt endeavour to cultivate the woollen manufacture, whoſe ſeeds are already ſown in this country.

I look on it as a loſs to Great Britain, and to arts and manufactures, that we have no academy inſtituted by public authority, and at the public charge, to which the care and further progreſs of theſe might be intruſted; and whoſe members, ſecured in a decent livelihood, might follow the natural bent of their genius; and hear, with ſafety, the enthuſiaſtic voice of Fame. What a trifling ſum to France is the yearly expence of the Academy of Sciences! and yet of what benefit has it been to the arts and manufactures of that country! Their ſuperiority in many arts, and eſpecially in dying, has been entirely owing to the labours of this ſociety. Lewis XIV. in whoſe reign this academy was inſtituted, has gained victories by it over thoſe whom his ſword could not ſubdue.

AN

EXPERIMENTAL ESSAY ON THE USE OF LEYS AND SOURS IN BLEACHING.

By JAMES FERGUSON, M. D.

In Artibus autem & ſcientiis, tanquam in Metalli fodinis, omnia novis operibus & ulterioribus progreſſibus ſtrepere debere.

Franciſci Baconi de Verulamio Cogitata & Viſa, p. 15.

TO THE

RIGHT HONORABLE AND HONORABLE

THE

TRUSTEES

OF THE

LINEN-MANUFACTURE.

THE FOLLOWING

ESSAY

IS, WITH PROPER DEFERENCE, INSCRIBED,

BY THEIR

MOST OBEDIENT AND

VERY HUMBLE SERVANT,

J. FERGUSON.

Belfaſt, Jan. 1ſt, 1766.

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PREFACE.

THE doctrine of fixed air, not long ſince introduced, hath opened a large field for improvements in natural knowledge: By it Dr. Black has explained the nature of Lime, in a new and ſatisfactory manner. By it Dr. Macbride has thrown light on ſome important ſubjects in Philoſophy and Medicine: and by it the Author's intention is to ſet the properties of Alkaline Salts in a new point of view, whereby he hopes to make ſome advances in the improvement of the art of Bleaching.

It having been found that the activity of bleaching aſhes was not increaſed, in proportion to their being freed from their earth, and it being ſuppoſed that the active parts of the Alkali were of a volatile nature; attempts have been made to prevent the eſcape of theſe fugitive parts, by melting the Aſhes in a great degree of heat, ſo as to form them into cakes. With a view alſo to improve their Aſhes, ſome have added Lime in the manufacture of them: but in ſome kinds there is too ſmall a quantity of Lime to anſwer the intended purpoſe; in one kind (the Muſcovy aſhes) the Lime is predominant; the bad effects of which, if they be uſed alone, need not be pointed out.

In the following Eſſay, the cauſe of this defect of Alkaline Salts is enquired into; and it is demonſtrated, that Lime is poſſeſſed of ſuch qualities, as to be capable of removing this defect entirely: and that if no more Lime be mixed with the bleaching-aſhes, than what is ſufficient to attain this end, the Lime, after bringing the Alkali to its higheſt degree of perfection, will fall to the bottom of the ley, deprived of its ſharpneſs.

In order to give a ſatisfactory account of theſe matters, it was neceſſary to prepare the way by a number of chymical experiments. Towards the end, ſome experiments are added, to enable bleachers to make a proper choice of their aſhes; and though Pearl-aſhes, to which the preference is given, were uſed in the trials of bleaching, herein mentioned; yet the fifteenth and ſixteenth experiments point out a method of determining the proportion of Lime, requiſite for any other kind of aſhes. And as there may be a difference in the ſtrength of Lime, or of aſhes, even of the ſame kind; an eaſy teſt is given at the ninth experiment, by which if leys be tried, it may be known inſtantly, and with the greateſt exactneſs, whether the quantity of Lime, uſed in preparing them, has been too large or too ſmall.

An enquiry is alſo made into the uſe of Sours, in the choice of which bleachers are aſſiſted; and rules are laid down for fixing a ſtandard for the ſtrength of them and of leys; ſo that, on the whole, it is hoped that bleachers will be at no loſs to conduct themſelves thereby in the uſe of leys and ſours.

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AN EXPERIMENTAL ESSAY.

THE art of Bleaching, has without doubt, been long known in the world, for we obſerve that fine linen is mentioned by Hiſtorians of the greateſt antiquity. But whether the antients uſed alkaline leys in bleaching; whether they depended chiefly on the action of the Sun, or what other method they made uſe of, we are at a loſs to know; as very little, if any thing hath been recorded upon this ſubject by antient writers.

But however effectual the heat of the Sun in warm Countries may be to whiten linen, yet in theſe cold Climates, other methods are requiſite to ſhorten the time of bleaching. Theſe methods generally depend, ſo far as I know, upon the uſe of alkaline leys, ſours, and ſoaps; and they appear to be ſupported by the dictates of reaſon, and by experience. For though by the Newtonian theory, the different colours of bodies depend upon the different degrees of refrangibility of thoſe rays of light, that are reflected from the bodies; yet the great Mr. Boyle (whoſe opinion with reſpect to the cauſe of colours in bodies, is ſimilar to that of Sir Iſaac Newton) enumerates various * ways, by which ſaline corpuſcles, in a fluid form, may alter the ſuperficies of bodies, upon which they act, and conſequently cauſe them variouſly to reflect the rays of light; one of which is, that ſuch a liquor may alter the colour of a body, by freeing it from an adventitious colour; and as an inſtance of it, he mentions his knowledge of a volatile liquor, that, incorporating with greaſe, could take ſuch ſtains out of cloaths. Something ſimilar to this happens in bleaching: a dark coloured ſubſtance is extracted by the leys out of linen, the quantity of which is leſſened in every ſucceeding proceſs: till at length, when the cloth is nearly white, the ley in which it is boiled, is ſcarcely tinged in the leaſt. The ſubſtance, on examination, is found to conſiſt of a ponderous oil, and ſome particles of earth †. But the Chymiſts generally agree, that alkaline ſalts, acids, and ſaponaceous ſubſtances are the proper ſolvents of bodies, that are of an oily nature; more eſpecially the alkaline ſalts, the activity of which, may however be greatly heightened, if to them there be added a certain proportion of quick-lime; for by this means, they become vaſtly more diſpoſed to attract and unite with ‡ oils; and thus to form a ſoap, which being ſoluble in water, may with eaſe be detached from linen. There

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* Boulton's Epitome of Boyle's Works, vol. ii. b. 4. c. 4.

† Home's Exp. on Bleaching, part 2. ſect. 2.

‡ Boerhaave's Elements of Chymiſtry, proceſs 13.

There have been great improvements made in the art of Bleaching, during the laſt thirty years: but much ſtill remains to be done. In order to its farther improvement, it is neceſſary that Bleachers ſhould be ſo well acquainted with the nature of the aſhes which they uſe, as to know upon what their activity depends, and how to form a judgment of their comparative value; what they contain, that is either uſeleſs or detrimental, and by what means to bring them to the higheſt degree of perfection, of which they are capable. There ſhould alſo be a certain ſtandard fixed, whereby the ſtrength of leys may be aſcertained. At preſent our bleachers vary greatly in the manner of uſing their aſhes: ſome ſprinkle them in the boiler on the cloth: ſome incloſe a certain quantity of them in a bag, which they lay into the furnace, while the cloth is boiling in it; others prepare a ley, but in ſo vague a manner, that the only teſt which they have of its ſtrength, is the taſte, and its oilineſs to the touch. Hence it is evident, that our bleachers are not acquainted with the moſt effectual manner of uſing their aſhes; for that method is beſt, by which the greateſt effect is produced with the ſmalleſt quantity, and which, if known, would no doubt be invariably purſued. As every endeavour to attain to this important end, will, it is hoped, be favourably received; a few hints ſhall be propoſed, in order to throw ſome light upon this ſubject.

As attempts are now making to introduce the uſe of Lime in bleaching: an inquiry into its nature and properties, as a whitening material, is the only method by which we can rationally ex-

expect to lay a ſure foundation for the ſafe and effectual uſe of it; and this is more neceſſary at preſent, when the Honourable TRUSTEES are to be determined in their opinion about the propriety of admitting or prohibiting the uſe of Lime, according to the ſucceſs or failure of the experiments, which they have appointed to be made.

It does not ſeem needful to enter into a detail of the opinions of the Chymiſts, in reſpect to the nature of Lime; it may be ſufficient to mention, that its virtues are, by ſome of them, attributed to certain igneous particles, inſinuated into the pores of the Lime-ſtone, whence ſome particles of water had been expelled by the force of the fire*;. but as the opinion, that we ought to entertain concerning the nature of Lime, will moſt evidently appear by demonſtrating the cauſe on which its activity depends; I ſhall proceed to this enquiry, beginning with the moſt obvious appearances.

Lime-ſtone, Chalk, or any other calcarious Earth, of themſelves mild, unactive and inſoluble in water, are by the action of a violent fire, converted into quick-lime, which is remarkably pungent to the taſte, is capable of diſſolving ſeveral ſubſtances, and ſtrongly attracts a large quantity of water, is ſlaked or reſolved into powder by it, and communicates its virtues to it. Now it ſeems to be the moſt natural way of proceeding, to enquire firſt into the change which calcarious earths undergo by the action of the fire: and this is clearly explained by the following experiments of Doctor **Black**.

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* Lemery's courſe of Chymiſtry, part 1ſt, chap. 11.

"Exp. 1. * He ſaturated two drachms of chalk with diluted ſpirit of ſalt; ſeven drachms and one grain of the acid finiſhed the diſſolution, and the chalk loſt two ſcruples and eight grains of air."

As white lime-ſtone is the kind that is uſed in this place (Belfaſt), I repeated the experiment with it, in the place of chalk: and found that the loſs of weight exactly correſponded with Dr. Black's account. The lime that I made uſe of in the following experiments, was prepared of this white lime-ſtone. I made the ſame trials with two kinds of lime-ſtone, raiſed out of quarries in the neighbourhood of Armagh, the one of a blackiſh colour, the other a dark red; and found that two drachms of the black kind loſt a drachm and ſeven grains of its weight, and the red kind loſt a drachm.

"† Exp. 2. Two drachms of chalk were converted into a perfect quick-lime, and loſt two ſcruples and twelve grains in the fire. This quick-lime was ſlaked or reduced to a milky liquor with an ounce of water, and then diſſolved in the ſame manner, and with the ſame acid as the two drachms of chalk in the preceding experiment. Six drachms, two ſcruples, and fourteen grains of the acid finiſhed the ſaturation, without any ſenſible efferveſcence or loſs of weight."

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* Edinburgh Eſſays and Obſervations, Phyſical and Literary, Vol. 2. page 194.

† Ibid. page 195.

Here we may obſerve that the chalk, in the firſt experiment, loſt two ſcruples and eight grains of air: and tho' the Doctor doth not make direct mention of an efferveſcence, yet he obſerves (page 166 of the Edinb. Eſſays) "that "a calcarious matter is attacked by an acid with "a briſk efferveſcence;" and (page 185) that "when we mix an acid with an alkali, or an abſorbent earth, the air is then ſet at liberty, "and breaks out with violence: becauſe the "alkaline body attacks it more weakly, than it "does the acid, and becauſe the acid and air "cannot both be joined to the ſame body, at "the ſame time."

Hence it may be concluded, that any alkaline matter is free from fixed air, when it doth not efferveſce with an acid: and on the contrary that its efferveſcing with an acid, is a proof that there is fixed air in it. Since then quick-lime was ſaturated with an acid, without any ſenſible efferveſcence or loſs of weight, it appears that no air was ſeparated from it by the acid: but that the air had been expelled by the action of the fire, to which the loſs of weight in the fire was, no doubt, chiefly owing.

Mr. Margraaf's experiment (as quoted by Dr. Black) is a farther proof, that calcarious earths really loſe a large quantity of air, when they are burned to quick-lime.

"* Exp. 3. He ſubjected eight ounces of oſteocolla to diſtillation in an earthen retort, finiſhing his proceſs with the moſt violent fire of a reverbeverberatory: and caught in the receiver only two drachms of water, which by its ſmell and properties, ſhewed itſelf to be ſlightly alkaline. He does not tell us the weight of the oſteocolla remaining in the retort, and only ſays, that it was converted into quick-lime; but as no calcarious earth can be converted into quick-lime, or bear the heat which he applied, without loſing above a third part of its * weight, we may ſafely conclude, that the loſs in his experiment was proportional, and proceeded chiefly from the diſſipation of fixed air," as it could not be retained in his veſſels under a viſible form. This concluſion is warranted by the remarks of chymiſts "who have often † obſerved in their diſtillations, that part of a body has vaniſhed from their ſenſes, notwithſtanding the utmoſt care to retain it; and they have always found upon farther enquiry, that ſubtil part to be air: which having been impriſoned in the body under a ſolid form, was ſet free, and rendered fluid and elaſtic by the fire."

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* Edinb. Eſſays and Obſervations, Vol. 2. page 187.

The above experiments plainly ſhew, that calcarious earths ſuffer no other change by being converted into quick-lime, than the loſs of a ſmall quantity of water, and of their fixed air. Let us now enquire by what means quick-lime may be deprived of its acrimony, and reſtored to its mild inactive ſtate; in order to which, it is neceſſary, firſt to obſerve what part of quick-

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* See 2d. experiment.

† Edinb. Eſſays and Obſervations, Vol. 2. page 174. See alſo Boerhaave's Elements of Chymiſtry, Vol. i. page 313.

lime it is that communicates its properties to water: and this is clearly proved by the following experiment of Dr. Black.

"* Exp. 4. He reduced eight grains of perfect quick-lime, made of chalk, to an exceeding ſubtile powder, by ſlaking it in two drachms of diſtilled water boiling hot, and immediately threw the mixture into eighteen ounces of diſtilled water in a flaſk: after ſhaking it, a light cloud, which floated through the liquor, was allowed to ſubſide; and the ſediment, when collected with the greateſt care, and dried, weighed, as nearly as he could gueſs, the third part of a grain; the water taſted ſtrongly of lime, had all the qualities of lime-water, and yielded twelve grains of præcipitate upon the addition of ſalt of tartar. The ſediment conſiſted partly of an earth, which efferveſced violently with aqua-fortis, and partly of an ochry powder, which would not diſſolve in that acid. The ochry powder he conſidered as an accidental admixture: and with reſpect to the minute portion of alkaline earth, which compoſed the remainder of the ſediment, he did not ſuppoſe it to have been originally different from the reſt, and incapable from its nature, of being converted into quick-lime, or of being diſſolved in water; but rather to have conſiſted of a ſmall part of the chalk, in its mild ſtate, or ſaturated with air, which had either remained for want of a ſufficient fire to drive it out entirely, or had been furniſhed by the diſtilled water."

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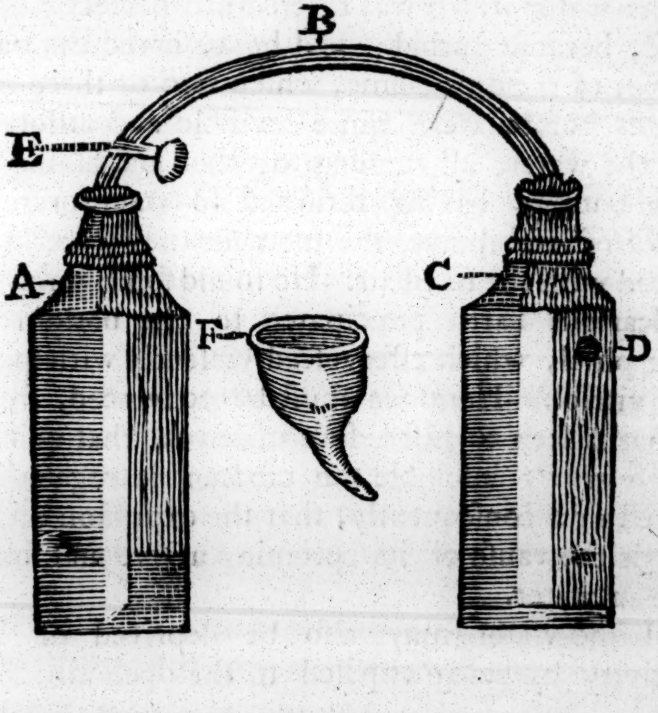
* Edinb. Eſſays and Obſervations, Vol. 2d. page 196, 197.

Hence it follows, that every particle of quick-lime is equally fiery, active, and ſubtile: and that the whole of it is capable of being diſſolved in water. Conſequently, that concluſions, with reſpect to the nature of lime may be drawn from experiments made with lime-water.

To this experiment Dr. Black ſubjoins a caution, that the calcarious ſubſtances uſed in making theſe experiments, ſhould be of the pureſt kind, and burned with the utmoſt violence of the fire.

Let us now attend to the following experiment of Dr. Macbride.

* Exp. 5. He put ſome lime-water in the phial marked A, in the neck of which there was



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* Macbride's Experimental Eſſays, eſſay 5th, page 215.

was an air-valve, which allowed the air to paſs into the bottle, but prevented its return: to the neck of this phial a bended brazen tube B, was fixed by a ſcrew; the other end of the tube was alſo fixed by a ſcrew, to the neck of the phial C, into which he had put ſome alkaline ſalt: in the upper part of this phial as at D, a ſmall hole was drilled, that thro' this aperture an acid might be gradually dropped in by the funnel F. Things being thus fixed, he poured in an acid, and during the effervefcence, ſtopped the hole at D, in order to force over the extricated air into the phial A; in a few minutes after the effervefcence began, and that the air, which was extricated from the mixture of acid and alkali, had paſſed over into the phial A, the lime-water which was filtered and perfectly limpid, became turbid; and he obſerved the particles of the quick-lime, which two or three minutes before were quite inviſible and diſſolved in the water, all running together and falling to the bottom, having returned to their original ſtate of inſolubility, the moment they were ſaturated with the fixed air. He found ſome grains of calcarious earth præcipated to the bottom of the phial, which effervefced violently with ſpirit of vitriol. Here we muſt be convinced, from what is ſeen to paſs before our eyes, that quick-lime grows inſoluble the moment it regains its fixed air: conſequently, that the expulſion of its air is the cauſe of its becoming active and ſoluble in water.

Lime-water may alſo be deprived of its activity by being expoſed to the open air: for by this means, "the * particles of quick-lime, which are neareſt the ſurface, gradually attract the particles of fixed air which float in the atmoſphere. But at the ſame time that a particle of lime is thus ſaturated with air, it is alſo reſtored to its native ſtate of mildneſs and inſolubility; and as the whole of this change muſt happen at the ſurface, the whole of this lime is ſucceſſively collected there, under its original form of an inſipid calcarious earth, called the cream or cruſts of lime-water."

† "When quick-lime itſelf is expoſed to the open air, it abſorbs the particles of water and of fixed air, which come within its ſphere of attraction; as it meets with the firſt of theſe in greateſt plenty, the greateſt part of it aſſumes the form of ſlaked lime, the reſt is reſtored to its original ſtate: and if it be expoſed for a ſufficient length of time, the whole of it is gradually ſaturated with air, to which the water as gradually yields its place."

As the knowledge of the proportion of lime, that a given quantity of water is capable of diſſolving, is quite neceſſary for the illuſtration of what follows: in order to determine this point, I made the following experiment.

Exp. 6. I prepared ſome lime-water, in the common method, with a large quantity of newly burned lime; as ſoon as the lime-water was perfectly clear, I took a pound of it, into which factitious air was transferred by an apparatus,

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* Edinb. Eſſays and Obſervations, Vol. 2d. page 189.

† Ditto in the ſame place.

ratus, which differed from Dr. Macbride's (deſcribed in the laſt experiment) by having a ſtop-cock E, placed near one end of the tube, inſtead of the air-valve in the neck of the phial A: when I ſuppoſed that the lime was fully ſaturated with fixed air, and by that means precipitated to the bottom of the phial; the water was filtered, and by different trials, it appeared to be perfectly free from lime. The calcarious earth when carefully collected and dried, weighed ſeventeen grains and a half. But it was obſerved, in the ſecond experiment, that calcarious earths loſe a third part of their weight in the fire, by the expulſion of their fixed air: it therefore follows, that lime, in recovering its mildneſs, by having its fixed air reſtored to it, will alſo regain its original weight.

Hence we may conclude that no more than about eleven grains and a half of lime, can be diſſolved in a pound of water: and alſo, that when the powder, præcipitated from clear lime-water, is in the proportion of ſeventeen grains and a half from a pint, there is not any lime remaining in the water.

Before we proceed to any experiments made with alkaline ſalts and lime-water, it muſt be premiſed, that alkaline ſalts, in their ordinary ſtate, contain a large quantity of fixed air, which is evident by their violent * efferveſcence with an acid. " Now if the † attraction of lime for fixed air, be ſtronger than that of alkalis, it follows,

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* See the concluſions drawn from the two firſt experiments.

† Edinb. Eſſays and Obſervations, Vol. 2d. page 192.

lows, that by mixing with it a ſufficient quantity of a common alkali, the lime will recover the whole of its fixed air, and be reſtored intirely to its original weight and condition;" for proof of this Dr. Black made the following experiments.

* " Exp. 7. A piece of perfect quick-lime, made from two drams of chalk, and which weighed one dram eight grains, was reduced to a very fine powder, and thrown into a filtered mixture of an ounce of a fixed alkaline ſalt, and two ounces of water. After a ſlight digeſtion, the powder being well waſhed and dried, weighed one drachm fifty-eight grains; it was ſimilar in every trial, to a fine powder of ordinary chalk, and was therefore ſaturated with fixed air, which muſt have been furniſhed by the alkali."

† " Exp. 8. A dram of pure ſalt of tartar was diſſolved in fourteen pounds of lime-water, and the powder, thereby præcipitated, being carefully collected and dried, weighed fifty-one grains: when expoſed to a violent fire, it was converted into a true quick-lime, and had every other quality of a calcarious earth."

In order to remove every doubt, that any lime is left in a ley, prepared of lime and a ſufficient quantity of alkaline ſalt: I made the following experiment.

Exp. 9. With a pint of lime-water, (the ſame of what was uſed in the ſixth experiment) I mixed a filtered ley, of thirty grains of pearl-aſhes

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* Edinb. Eſſays and Obſervations, Vol. 2d. pages 195, 196.

† Ditto page 196.

aſhes and an ounce of water ; the mixture immediately became turbid and milky, and in a ſhort time depoſited a white ſediment, which when dried, weighed ſeventeen grains and a half. Now it * appeared that the powder depoſited from a mixture of an alkali and lime, was a true calcarious earth ; therefore the † whole of the lime was præcipitated from the water. But as the filtered ley loſt its tranſparency upon adding to it ſome clear lime-water, I ſuſpected that I had uſed more of the alkali than what was ſufficient to ſupply the lime with fixed air : I therefore repeated the experiment with twenty-ſix grains of pearl-aſhes: and the filtered ley continued clear, when tried either with lime-water, or a ley of pearl-aſhes: which is an evident proof, that the quantity of alkali was exactly proportioned to a pint of lime-water ; for in the former part of the experiment it appeared, that whether the lime or alkali was predominant, the liquor became turbid, on being mixed with the other.

This experiment then points out a complete teſt, by which to prove any ley, made of lime and alkaline ‡ ſalts: for its loſing its tranſparency, on being mixed with clear lime-water, is a proof that too much of the alkali has been uſed in making it: but if on the contrary, it becomes turbid by a mixture with a clear ley of pearl aſhes, there has not been a ſufficient quantity of alkali uſed to præcipitate the whole of the lime.

I will

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* See experiments 7th, and 8th.

† See Experiment 6.

‡ This is conformable to what Dr. Black communicated to me.

I will only add the following experiment of Dr. Black, which is very concluſive with reſpect to the nature of lime.

* Exp. 10. Half an ounce of chalk was diſſolved in ſpirit of ſalt, the quantity of which was ſo adjuſted, that the mixture was not acid in the leaſt degree: and the ſolution was thrown into twelve ounces of a ley free from air, which quantity he found by experiment, to be ſufficient for præcipitating almoſt the whole of the chalk. He now filtered this turbid liquor, and laid the powder remaining in the paper, upon a chalkſtone, in order to draw as much of the water from it as poſſible, and thereby reduce it to the form of a more denſe and heavy powder, that it might ſubſide the more perfectly in the following part of the experiment. He then mixed it with about twenty ounces of pure water in a flaſk: and after allowing the powder to ſubſide, poured off the water, which had all the qualities of lime-water. He ſucceſſively converted eight more waters into lime-water: ſeven of them in the ſame quantity, and with the ſame management as the firſt; the eighth was likewiſe in the ſame quantity, but he allowed it to remain with the chalk, and ſhook it frequently for two days: this, after being filtered, formed a cream or cruſt upon its ſurface when expoſed to the air, changed the colour of the juice of violets into green, became turbid upon the addition of an alkali;" and by other trials it had the evident properties of lime-water.

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* Edinb. Eſſays and Obſervations, Vol 2d. pages 206, 207.

" In this experiment, therefore, the air is firſt driven out of the chalk by an acid, and then, in order to ſeparate this acid from it, we add an alkali, which has been previouſly deprived of its air, by which means, the chalk itſelf is alſo obtained free of air, and in an acrid form, or in the form of ſlaked lime."

Having thus ſeen that the activity of lime, and its ſolubility in water, entirely depend on the expulſion of its fixed air : Let us now enquire into the cauſe to which the properties of a fixed alkaline ſalt may be attributed.

* This ſalt is produced by fire, while it actually conſumes vegetables that are fit for that purpoſe. If any part of the oils be left adhering to the ſaline matter: or if the plant be burned with a ſlow ſmothering fire, the ſalt will be leſs acrid ; but if it be expoſed to a ſtrong open fire, the acrimony will be the greater, which will be the more increaſed the longer it is kept in the fire, and the intenſer the heat is, to which it is expoſed. Boerhaave † even aſſerts, that the proper action of the fire ſeems to add ſomething of an igneous quality to the alkali: yet he doubts whether this ariſes from the fixing of the very ſubſtance of the fire itſelf to the ſalt, or only from a power that the fire poſſeſſes of altering it in a particular manner. But Mr. Boyle ‡ thinks it is precarious to argue, that a fixed alkaline

ſalt has fire in it: becauſe the inflammable parts, which are moſt likely to belong to the element of fire, muſt probably be forced away, by the time that the fire hath reduced the body to aſhes.

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* Boerhaave's Elements of Chymiſtry, Vol. 2d. proceſs 13th, in the Corollaries.

† Ditto in the ſame place.

‡ Boulton's Epitome of Boyle's Works, Vol. 4th, page 96.

The production of an alkali, by burning a plant in the open fire, does not diſcover its nature: for all the volatile parts do thus eſcape our examination; but Boerhaave, in the fifty-fifth proceſs of his Elements of Chymiſtry, ſeems to caſt ſome light upon this ſubject: for by diſtillation in a retort, he reſolved tartar into an acidilous water, a penetrating ſpirit, an oil, and a fixed alkaline ſalt. In this proceſs it is to be obſerved, that all the volatile parts were expelled out of the retort, during the diſtillation, that he could not uſe an impenetrable lute to his veſſels leſt they ſhould be burſt aſunder by the great quantity of air during the proceſs; and that, in proportion to the quantity of air which was ſeparated, the remaining maſs was more acrid, and approached nearer an alkaline ſtate.

This is, perhaps, the only inſtance, where a fixed alkaline ſalt is produced in a veſſel, without the admiſſion of any air; let us then attempt to diſcover by what means an alkali may be rendered mild and inactive.

* If an alkaline ſalt be diſſolved in water, and filtered, there remains a ſubſtance in the paper like earth, which will not diſſolve in water; if the clear liquor be evaporated by a ſtrong fire, and

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* Boulton's Epitome of Boyle's Works, Vol. 4th, page 128. See alſo Boerhaave's Elements of Chymiſtry, Vol. 2d. page 40.

and the ſalt thus procured, be again diſſolved in water, an earth will be left in the filtre as before: and if theſe operations be ſufficiently repeated, the whole may be reſolved into earthly fœces. Now in order to find out how an alkali may be converted into earth, I made the following experiments:

Exp. 11. I ſaturated a clear ley, made by diſſolving half an ounce (or two hundred and eighteen grains) of pearl aſhes in water with a diluted ſpirit of vitriol: and found that it loſt fifty grains of fixed air, the loſs of weight being to the whole nearly in the proportion of three to thirteen.

Exp. 12. I then procured thirty grains of earth from the ſame parcel of aſhes, (by ſolution and filtration of them) which loſt 9 grains of fixed air, during its efferveſcence with the ſame diluted acid, being as three to ten.

Hence it appears, that the earth of an alkali contains more fixed air, than does the alkali itſelf. By theſe experiments I was induced to try, what would be the effect of transferring fixed air into an alkaline ley.

Exp. 13. Accordingly I diſſolved four ounces of pearl-aſhes in twenty ounces of water, and after filtration, laid up four ounces of the clear ley for a ſtandard; I then transferred factitious air from an efferveſcent mixture, by the apparatus uſed in the ſixth experiment. The ley did not begin to grow turbid till after twelve hours ſtanding: next day a ſediment was depoſited; at the end of four days I carefully collected and dried the precipitate, which weighed nine grains, and was quite inſipid. The ley was much milder to the taſte than the ſtandard, and an ounce of it was ſaturated with a fourth part leſs of an acid than was required to bring an ounce of the ſtandard to a neutral ſtate.

This experiment then points out a manner, by which an alkali may be converted into earth: whence the cauſe of its activity is not obſcurely hinted; for ſince the ley is rendered milder, and ſome earth is depoſited, of which no other cauſe can be aſſigned, than the abſorption of fixed air; may it not hence be fairly concluded, that the expulſion of a certain proportion of fixed air, while an alkali is generating, is the cauſe of the degree of acrimony, of which it is poſſeſſed: and conſequently that its acrimony and activity are increaſed, in proportion to the quantity of air expelled from it. Do we not alſo here obſerve, that an alkali, though much weakened by the attraction of fixed air, is not deprived of its ſolubility in water, till it be ſo fully ſaturated with air, as to be converted into an earth that is perfectly inſipid?

This ſubject is farther illuſtrated, by attending to the cauſe and effects of putrefaction. Boerhaave, in the eighty-eighth proceſs of his elements of Chymiſtry, ſhews that a volatile alkaline ſalt may be procured from a plant of whatſoever kind it be, by diſtilling it when reduced to a putrid maſs; and Dr. Macbride has made ſeveral * experiments on putrid animal ſubſtances, as

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* Experimental Eſſays, eſſays 2d, Exp. 26th, to 34th.

as a concluſion from which, he joins with Neuman in * ſaying, that as ſoon as an animal ſubſtance begins to putrefy, it begins to diſcover an alkaline quality, and that this volatile matter now produced in it, may be ſeparated by diſtillation in a very gentle warmth.

But by the ſixteenth experiment of his ſecond eſſay, and the eighth experiment of his fifth eſſay, Dr. Macbride demonſtrates, that during the progreſs of putrefaction, there is continually ſome volatile matter flying off from the putrefying ſubſtance, and that this fugitive principle is air, which is now extricated and thrown off, from a fixed and non-elaſtic ſtate, into one that is volatile and elaſtic; but which immediately, upon meeting with a proper recipient, (as lime-water) returns again to its former ſtate (and precipitates the lime to the bottom of the phial.) That the loſs of the fixed air of putrefying bodies is the cauſe of their putrefaction, is farther proved by ſeveral experiments in his third eſſay: for by reſtoring air to putrid fleſh from an efferveſcent or fermenting mixture, the fleſh recovered its ſoundneſs and ſweetneſs again.

Since then the progreſs of putrefaction depends on the eſcape of fixed air from the putrefying body, and ſince putrid ſubſtances readily yield a volatile alkaline ſalt, from many of which it could not be procured before their putrefaction: does it not appear hence, that the alkaline property is owing to the expulſion of at leaſt a part of the fixed air? It may be here objected,

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* Experimental Eſſays, page 104, 105.

jected, that this concluſion is too general: for that it is a volatile alkali, which is produced by putrefaction; but a volatile and a fixed alkali * agree in all their alkaline properties: their chief difference conſiſts in their being volatile or fixed.

Here we might reſt, and from the properties of lime and alkaline ſalts already explained, infer the utility of lime in bleaching; for if the activity of an alkali depends on the expulſion of its fixed air, if it be not entirely free from air: and if the remaining fixed air can be expelled by a proper quantity of lime (as has been ſhewn above,) the propriety of uſing lime might readily appear. Yet as the advantage of freeing an alkaline ley from its fixed air may not be fully known, the following experiment of Dr. Macbride, tends to ſet it in a clear light.

† Exp. 14. He transferred air from an efferveſcent mixture, into a ſolution of common ſoap: and the moment the air mixed with the ſolution, the oily part began to ſeparate, and in a few minutes all roſe to the ſurface: the fixed air now being reſtored to the diſ-united particles of the oil.

Since then the oily part was ſeparated from the water on having its air reſtored, it is evident that it was rendered miſcible with water, when the cohesion of its particles was deſtroyed by the loſs of its fixed air; but it appears, by comparing the fifty-firſt and fifty-ſecond pages of

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* Boerhaave's Elements of Chymiſtry, Vol. 1ſt, page 462.

† Macbride's Experimental Eſſays, eſſay 5th. Exp. 5th.

Dr. Macbride's Eſſays with the thirteenth experiment here, that leys free from fixed air, have a ſtronger attraction for fixed air, than thoſe which are nearly ſaturated with it; conſequently, leys will be more or leſs effectual in deſtroying the coheſion of the particles of oil, and in rendering it miſcible with water, in proportion to their being more or leſs freed from their fixed air. This perfectly correſponds with the practice of ſoap-boilers, who uſe ſo much lime, as that all the fixed air may be extracted from their leys: by which means the boiling of their ſoap is completed in a ſhorter time.

The application to bleaching is very clear; it was obſerved before, that whitening of linen is effected by extracting from it the colouring oils, which can beſt be done by making them miſcible with water; but we have ſeen, that the moſt effectual method of attaining this end is the uſe of leys which are free from air: they moſt powerfully attract and unite with the colouring oils, and thus cauſe them moſt readily to mix with the water, ſo as with eaſe to be detached from the cloth.

If then leys, free from fixed air, be moſt effectual in bleaching, does not the advantage appear of mixing ſo much lime with our aſhes, as is ſufficient to attract the whole of their fixed air, and thus to bring them to their higheſt degree of perfection?

If it be objected, why may not ſome other method be taken to extricate the fixed air from the alkali, than a mixture of it with lime? to this it is anſwered, that no other way is effectual.

tual. Dr. Black indeed, found by * experiment, that an alkali does really loſe a part of its air, and acquire a greater degree of acrimony, by the proper application of heat; but found that the air could not be entirely expelled, which he imputed to the propenſity of the alkali to diſſipation in the utmoſt violence of the fire, to its extreme acrimony, and to the imperfection of our common veſſels; for before the heat becomes very intenſe, the alkali either evaporates or diſſolves a part of the crucible in which it is contained, and often eſcapes through its pores; this happens, eſpecially, as ſoon as it has already acquired ſome degree of additional acrimony by the loſs of its air.

The moſt advantageous manner, therefore, that we have of uſing our bleaching-aſhes, is to mix them with lime: the proportions of which are determined by the following experiment.

Exp. 15. I diſſolved half an ounce (two hundred and eighteen grains) of pearl-aſhes in eight ounces of water, and after allowing it to ſettle, I poured the clear ley into a flaſk: I then put a bottle, containing diluted ſpirit of vitriol, and the flaſk, into the ſame † ſcale of a well ſuſpended balance; having brought the balance to an exact equilibrium, I took out the bottles, and gradually poured the acid upon the alkali, till it was fully ſaturated: I then, by a ſmart blaſt of a pair of bellows,

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* Edinb. Eſſays and Obſervations, Vol. 2d. pages 211, 213.

† The method of finding out the quantity of air, contained in an alkali, was communicated to me by Dr. Black.

bellows, forced the air out of the flaſk, which had been extricated during the effervefcence: when replacing both bottles in the ſame ſcale as before, I found that it required fifty grains to reſtore the equilibrium.

I repeated the ſame experiment with the ſame quantity of another kind of pearl-aſhes, which loſt fifty-ſix grains of fixed air.

I made the ſame trial with leys made of equal quantities of kelp, of caſhub-aſhes, and of two kinds of barilla-aſhes: with only this difference, that in making leys of theſe aſhes, I reduced them to powder, and boiled them in water a few minutes over the fire, in order to diſſolve their ſalts the more completely. The reſult was, that two hundred and eighteen grains of kelp loſt twenty grains of air: the ſame quantity of caſhub-aſhes loſt alſo twenty grains: the ſame weight of the ſweet kind of barilla-aſhes loſt thirty-two grains of air: and the other ſort of barilla-aſhes loſt fifty grains of fixed air.

Now it was proved by the ſixth experiment, that no more than eleven grains and a half of lime can be diſſolved in a pound or pint of water, which is in the proportion of four pounds avoirdupois to three hundred gallons of water, (reckoning twenty-ſeven grains in the drop, and overlooking the fraction of a grain, which can make no material difference in the computation.) It alſo appeared in the ſecond experiment, that lime-ſtone loſes a third part of its weight in the fire; conſequently four pounds of lime weigh ſix pounds before it is burned, and hence require two pounds of fixed air to reſtore it to the ſtate of lime-ſtone, and precipitate it to the bottom of the veſſel, when it is diſſolved in water. But it is demonſtrated in this experiment, that kelp loſes twenty grains of air, out of two hundred and eighteen grains: or which is the ſame, one eleventh part of its whole weight is fixed air; therefore twenty-two pounds of kelp contain two pounds of fixed air, which quantity is ſufficient to ſaturate four pounds of lime; and if they be uſed in this proportion, for making three hundred gallons of ley, all the fixed air will be extracted from the kelp, and all the lime will be depoſited in the form of powdered lime-ſtone to the bottom of the veſſel.

Caſhub-aſhes ſhould be uſed in the ſame proportion as kelp, becauſe they loſt equal quantities of air: and by the rule of inverſe proportion, the requiſite quantity of any other kind of aſhes may be found out. To give examples in whole numbers without regarding fractions, the ſweet kind of barilla-aſhes, which loſt thirty-two grains of fixed air, muſt be uſed in the proportion of fourteen pounds to four pounds of lime: whereas nine pounds will be ſufficient of the kind of pearl-aſhes which loſt fifty grains of air: and only eight pounds are required to four pounds of lime, of that kind of pearl-aſhes which loſt fifty-ſix grains of fixed air.

Hence a method is ſuggeſted of adjuſting the proportion of any kind of lime, differing in ſtrength from that prepared of white lime-ſtone; which is, by ſubſtituting in place of the four pounds mentioned in this experiment, ſuch a quantity of any other kind of lime, as may be found to require two pounds of fixed air, to reſtore it to the ſtate of lime-ſtone. Now by comparing the firſt and ſecond experiments, it appears that the loſs of weight is nearly equal, whether the lime-ſtone be diſſolved in ſpirit of ſalt, or be converted into lime in the fire. If then any kind of lime-ſtone be diſſolved in ſpirit of ſalt, and the loſs of weight found out by the method uſed in the firſt part of this experiment; from the loſs of weight it ſuſtains during the ſolution, it may be eaſily computed what quantity of lime prepared of it, would require two pounds of fixed air to reſtore it to the ſtate of lime-ſtone. For inſtance, the blackiſh kind of Armagh lime-ſtone was * found to loſe the half of its weight, while diſſolving in the ſpirit of ſalt: Hence two pounds of lime, prepared of it weigh four pounds before it is burned, conſequently require two pounds of fixed air to reſtore it to the ſtate of lime-ſtone: ſo that no more of this kind of lime muſt be taken, than half the quantity that is neceſſary, of lime prepared of white lime-ſtone.—In the ſame manner the proportion of any other kind of lime may be determined.

Hence alſo it appears, that pearl aſhes contain more fixed air than either kelp or caſhub-aſhes, it may readily be known, why the whitening powder of aſhes is not increaſed in proportion to their being freed from their earth; and why pearl-aſhes are more improved, by being mixed with lime, than either of the other two.

The

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* See the firſt experiment.

The quantity of lime now mentioned, is very near as much as can be diſſolved in three hundred gallons of water, which it will fully ſaturate, provided the lime be completely burned; but as our common lime is not very good, I made the following experiment, in order to determine the quantity that remains undiſſolved.

Exp. 16. I took eleven grains and a half of the flower of common lime, newly burned, to which I added a pound of water; after frequent ſtirrings it was allowed to ſubſide: there was a ſmall ſediment at the bottom of the veſſel, and I could ſcarcely procure thirteen grains of precipitate from the lime-water, by transferring air into it: whereas ſeventeen grains and a half ſhould have been precipitated, had the eleven grains and a half of lime been quite diſſolved.

This experiment I repeated ſeveral times with the ſame event: whence I concluded, that a full fourth part remained undiſſolved, and that it was neceſſary to take a pound more of lime than the ſtandard fixed above for making three hundred gallons of ley.

Having thus determined the proportions of lime and bleaching-aſhes, neceſſary to make a ley, which will not only be effectual, but perfectly ſafe in its operation: I will now proceed to point out a method, by which bleachers may form a judgment of the value of their aſhes. It will, I believe, be granted that all bleaching-aſhes are to be eſtimated in proportion to the quantity of alkaline ſalts contained in them, and by their being free from any mixture, which can either

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* See experiment 6th.

either retard the operation of the * alkali, or be hurtful to the linen. Having premiſed this obſervation I will recount ſome experiments which will, I hope, illuſtrate this ſubject.

Exp. 17. I prepared ſeparate leys, with equal quantities of water, and equal weights of pearl-aſhes, caſhub-aſhes, and the ſweet ſort of barilla-aſhes: and found that their ſpecific gravity (as proved by a hydroſtatical ball) bore the following proportion, viz. The ley of pearl-aſhes was to that of caſhub-aſhes, as eight to three, and to that of barilla-aſhes, as fourteen to eight; but the ſpecific gravity is in proportion to the quantity of ſalt diſſolved in the leys; hence three pounds of pearl-aſhes contain as much alkaline ſalt, as eight pounds of caſhub-aſhes: and eight pounds of pearl-aſhes have an equal quantity of alkali, with fourteen pounds of barilla-aſhes. † I could not make an eſtimate

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* The fixed air, which is more or leſs in almoſt every kind of aſhes, is not taken into this account; becauſe it is ſuppoſed that whatever kind of aſhes is choſen for uſe, the fixed air will be expelled by lime, according to the method pointed out in the two laſt experiments.

† The following experiments were made by Dr. Lewis for determining the ratio in which alkaline ſalts increaſe the gravity of water: by which we may be enabled to form a judgment with ſome preciſion, from the weight of the ley, of the quantity of ſalt diſſolved in it. (See Neuman's Chymiſtry, by Lewis, page 467.)

Difmate of the quantity of alkaline ſalt, contained in kelp or the common barilla-aſhes: becauſe their ſpecific gravity is greatly increaſed by the large quantity of ſea-ſalt which they contain.

The mixtures that are found in aſhes, are either ſulphur or ſea-ſalt, or both together. Dr. Home has made it appear, that there is neither ſulphur nor ſea-ſalt in pearl-aſhes: that there is ſulphur both in caſhub-aſhes, and in kelp, and that the quantity of ſea-ſalt in kelp, is nearly equal to a fourth part of its whole weight; but he made no trial of either kind of barilla-aſhes to prove them.

Exp. 18. I prepared a ley of two ounces of the ſweet ſort of barilla-aſhes, and three pounds of water: this ley tinged ſilver in ten minutes, and in an hour made it quite black. When it was boiled away to two ounces, ſilver dipped in it, grew inſtantly yellow, but there was no appearance of ſea-ſalt in it. When the vitriolic acid was dropped on the dry aſhes, a ſtrong ſulphureous ſmell aroſe from them; from the whole we

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Different proportions of a fixed alkaline ſalt were diſſolved in pure water, and equal meaſures of the ſeveral ſolutions were weighed in a narrow-necked glaſs, which held ſixteen ounces of water; a mark was made with a diamond in the neck at that part to which this quantity of water aroſe, and the bottle was filled to the ſame height with each of the other liquors. The reſult of the experiments was as follows:

When

we may conclude that there is a large quantity of ſulphur in theſe aſhes.

I made the ſame trials with the other kind of barilla-aſhes, which does not appear to contain ſo much ſulphur as the ſweet kind; but when the ley was boiled away to two ounces, it taſted like brine, was full of ſea-ſalt, and begun to chryſtallize: ſo that it nearly reſembles kelp in

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When ſixteen ounces of the liquor by weight, contained of ſalt.		The meaſure of the liquor weighed more than 16 ounces, or more than an equal meaſure of water, by		
oz.	dr.	oz.	dr.	gr.
0	4	0	1	40
1	0	0	3	30
1	4	0	5	00
2	0	0	7	30
2	4	1	1	30
3	0	1	3	30
3	4	1	5	00
4	0	1	7	20
4	4	2	1	22
5	0	2	3	25
5	4	2	5	02
6	0	2	7	30
6	4	3	1	30
7	0	3	3	28
7	4	3	5	01
8	0	3	7	30
8	4	4	1	30

in the quantity of ſea-ſalt and ſulphur that it contains.

It is unneceſſary to prove the hurtfulneſs of ſea-ſalt in bleaching: for every one knows that it has a tendency to make linens thin. That ſulphur retards the operation of an alkali, appears by the following experiment.

Exp. 19. I prepared equal quantities of two leys, the one of pearl-aſhes, and the other of caſhub-aſhes: they were made of the ſame ſtrength or ſpecific gravity, and were freed from their fixed air by a ſufficient quantity of lime; I then took one hank of yarn, which I divided, and boiled one half of the yarn in the one, and the other half in the other ley, for three hours; when they were both well waſhed and dried, I found that the half boiled in the ley of pearl-aſhes, was much whiter than the other, and had loſt a fourth part of its weight; whereas the

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As the ſpecific gravity of water is increaſed by an addition of the oil of vitriol, this table may alſo point out a method of determining the ſtrength of ſours, to thoſe who have not a hydroſtatical ball; for inſtance, if a pint of the liquor prepared for the firſt ſour, weighs five drachms more than a pint of water, and if this liquor be found, by the rule to be afterwards given, to be of a proper degree of ſtrength; let the firſt ſours be afterwards prepared ſo, as that a pint of them will weigh five drachms more than a pint of water.

A ſtandard for the ſubſequent ſours may be fixed after the ſame manner.

the other half that was boiled in the ley of caſhub-aſhes, had loſt two eleventh parts only.

Hence it is evident, that the whitening power of the alkali is greatly leſſened by ſulphur, and conſequently that pearl-aſhes are to be preferred to any kind of aſhes, that hath ſuch a mixture in it.

The next thing that preſents itſelf to our enquiry is, which of the two methods of bleaching, (viz. boiling or bucking) ought to be preferred for its efficacy and ſafety. This queſtion I will not abſolutely determine, but will content myſelf with propoſing the following conſiderations upon this ſubject. I believe, from what has been already advanced, it will readily be granted that leys whiten linen, by acting as a menſtruum on its colouring oils; now the whole ſolvent never acts at once upon the whole body of the ſolvend; but the particles of the ſolvent act only upon thoſe of the ſolvend, with which they come into contact; therefore it is neceſſary that there ſhould be a ſucceſſive application of them to one another, which will be greatly aſſiſted by heat, more eſpecially when the particles of the menſtruum are all put into motion by the action of boiling; hence it would appear, that leys act with the greateſt advantage when in a boiling ſtate.

If it be objected that boiling is more ſevere upon the linen than bucking is, it may be anſwered, that boiling a ſhorter time, and in a weaker ley, will prevent any bad effects from it; in ſhort, this method is found by experience to be quite ſafe and effectual: yet how long linens ſhould be boiled, muſt be determined by future trials.

However, whether linen be boiled or bucked, the ley ought to be well waſhed out of it, before it be ſpread upon the green; the benefit which may be expected from leaving the ley in the cloth is overbalanced by the riſque incurred by it: for it is a thing next to impoſſible, for linen that is expoſed to a warm ſun with the hot ley in it, to be preſerved wet; now it is well known, that ſafety in the uſe of alkaline ſalts, depends upon their being diſſolved in a large quantity of water, ſo ſoon therefore as the water is nearly evaporated by the heat of the ſun, the ſalts, (no longer ſufficiently diluted), act with too much force upon the cloth; as a proof of this, I appeal to all intelligent bleachers, whether their linens be not whitened with greater ſafety, ſince this practice of waſhing out the ley has been adopted by them?

Here I cannot avoid remarking the bad practice of ſome bleachers, who make uſe of the ſame leys for three or four different times, with the addition of a ſmall quantity of freſh to what they call the burned ley. It was obſerved before, that a dark-coloured ſubſtance is extracted by the leys out of linen, which is diſcovered to be of an oily nature: now it is well known, that leys by uniting with oils, have their activity greatly abated, (for inſtance, in ſoap:) beſides it appeared, by the thirteenth experiment, that alkaline leys have an attraction for fixed air, and are rendered weaker by the abſorption of it; therefore leys often uſed, and by ſuch means nearly ſaturated with fixed air out of the linen, can have but ſmall effect in bleaching, if not a bad one, by tinging the cloth with the colouring oils, with which they are greatly impregnated.

It alſo was proved in the thirteenth experiment, that ſome earth was precipitated from a ley by its abſorption of fixed air. As part therefore of the alkali is thus converted, during each proceſs, into earth, which in part precludes the action of ſucceeding leys: it is neceſſary to take this earth out of the cloth, and this can only be done by the uſe of * acids; for earth does not diſſolve in water, but it is attracted by acids, and compoſes with them a kind of neutral ſalt, which is ſoluble in water, and therefore eaſily waſhed out of the cloth. When theſe abſorbent particles of earth are fully † ſaturated, the remaining acids may unite with, and have ſome effect in extracting the colouring particles; but for this purpoſe, I would prefer the leſs exceptionable uſe of leys, becauſe acids when ſtrong, have a tendency to deſtroy the tenacity of the linen: for let enquiry be made of an obſerving bleacher, whether, when cloth is weakened, it does not generally happen during the laſt times of ſouring? whether it be not certain that the danger increaſes, in proportion to the number of ſourings? and whether he does not obſerve in the ſecond and ſubſequent ſourings, that the ſour retains a conſiderable degree of acidity, even after

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* Home's experiments on bleaching, page 76th.

† Ditto page 78th.

ter the cloth is taken out? If anſwers to theſe quæres be made in the affirmative, as by right they ſhould: does it not follow that theſe ſours ought to be juſt ſo ſtrong, as that their acidity may be loſt by their action on the abſorbent earth in the cloth?

As therefore, the freeing linen from the abſorbent particles of earth is the principal end that we ſhould have in view by the uſe of acids: what good reaſon can be aſſigned for deferring the application of them, till the cloth is nearly white: and for repeating the uſe of them when it has been boiled only once, and conſequently cannot be ſuppoſed to have much earth lodged in it, on which the ſours may act? certainly an earlier application of acids would prepare the linen for a more beneficial uſe of the leys: and after ſome intervening boilings, the ſours might again be uſed with greater ſafety and advantage to the cloth.

That acids may be uſed with ſafety, they ſhould be brought to a certain ſtandard of ſtrength, which ought not to increaſe during their action on the linen: they ſhould alſo be incapable of putrefaction: By theſe teſts then, let us examine the ſeveral ſours that have been commonly uſed, which are buttermilk, infuſions of wheat or bran, &c. and the vitriolic acid plentifully diluted; now, in order to form a judgment of this matter, we muſt attend to the changes to which theſe ſubſtances are liable. "When an * infuſion of vegetables is left to itſelf,

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* Macbride's Experimental Eſſays, eſſay 1ſt. page 8th.

itſelf, in a few hours an inteſtine motion begins, eſpecially if it be expoſed to a moderate heat: this Dr. Macbride calls the firſt or ſweet ſtage of fermentation; then follows the ſecond or ſour ſtage, as turning the ſubject manifeſtly ſour: the third, or putrid ſtage ſucceeds, when the texture of the ſubſtance fermented is fairly deſtroyed, and it becomes rotten and offenſive."

* "Again, milk in a few days naturally contracts an acidity, which muſt be conſidered as the effect of a fermenting motion, diſcovering in that liquor an acid, that was not perceptible before; this properly ſpeaking, being an acetous fermentation, which the milk paſſes through in its way to putrefaction, and which ſoon follows if it be expoſed to a hot air."

Now if linen be put into any of theſe ſours, during the ſecond or acetous ſtage of fermentation, their ſtrength cannot be aſcertained: for the acidity of them is increaſing every hour, and the change is more ſpeedy when the weather is warm: therefore the bleacher cannot determine what time is ſufficient to keep the cloth in ſuch a variable ſour; if the linen be not put in till the ſour has acquired its greateſt degree of acidity, the putrid ſtage of fermentation is faſt approaching: and ſhould it begin, the liquor will no longer act as a ſour, but as a putrefactive ferment, by which the firmneſs of the linen will be moſt certainly impaired. The offenſive ſmell fre-

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* Macquer, as quoted in Macbride's Experimental Eſſays, eſſay 1ſt. page 18th. in the note.

frequently obſervable in the ſouring veſſels, where theſe ſours are uſed, is a proof that they often are in a ſtate of putrefaction; beſides I appeal to experienced bleachers, whether they have not known linen much damaged while theſe ſours were commonly uſed, and whether they do not obſerve the vitriolic acid to be much ſafer for the cloth: it can be brought to a certain ſtandard of ſtrength, which will not increaſe while it is acting on the linen: it is not affected by the weather; it ſooner produces the effects expected from it, and it is not capable of putrefaction.

I have only to add, that it is the common practice after the linen is drawn out of the ſour, to waſh it, ſoap it, and paſs it through the rolling-boards. Now every bleacher muſt certainly have obſerved the great difficulty of raiſing a good lather with the ſoap, though a greater quantity of it than ordinary be made uſe of; by which means the linen incurs great hazard of being holed. This is occaſioned by ſome part of the ſour which remains in the cloth, and which by attracting the leys out of the ſoap, diſſolves the union between them and the oil, ſo that it is incapable of being mixed with water, or of raiſing a lather: but it is eaſily prevented by giving the linen a ſlight boil in ley before the ſoap be rubbed on it.

As I have now finiſhed what appears to be neceſſary for the explication of ſuch things as do not ſeem to be underſtood by bleachers, with reſpect to the uſe of leys and ſours: and as it is not my intention to inſiſt on what is well known to every artiſt, I will proceed to give an account of my experiment of bleaching with lime. After the twelve pieces of linen had been ſteeped in the uſual way, they were boiled two hours in a kelp ley, made in the following manner and proportions. Twenty-two ounces of kelp reduced to powder, were mixed with five ounces of the flower of lime newly burned: to which was added ſo much water, as to bring the whole to the conſiſtence of a fluid paſte; this was ſtirred frequently in a tub, for near an hour, and then thrown into the kelp-keeve, whence ſeventy-five quarts of ley were drawn off by the common method into the receiver, and reſerved for uſe. This ley was of a proper degree of ſtrength, when mixed with an equal quantity of water; in it the cloth was boiled two or three times, then a ley was uſed, which was thus prepared: Eight ounces of that kind of pearl-aſhes which loſt ſixty-ſix grains of fixed air out of half an ounce, were digeſted with five ounces of the flower of newly burned lime in the manner deſcribed above: and after being ſtirred during an hour, the mixture was diluted with ſeventy-five quarts of cold water, and then allowed to grow clear and fit for uſe. I ordered the bleacher to prove the ley by the method directed in the ninth experiment, and if it became turbid in the leaſt degree, when a clear ſolution of pearl-aſhes was mixed with it, I deſired him to add half an ounce more of the aſhes to the ſeventy-five quarts of ley: but he ſcarcely ever had occaſion to make any addition to it.

I would not chuſe to prepare more ley at a time, than what could be conſumed in two days at fartheſt: becauſe in a ſhort time it loſes part of its activity, by attracting fixed air out of the * atmoſphere. I was confirmed in this opinion by the bleacher's obſervation, that this ley was moſt effectual when it was newly made: yet even ſo, if a large quantity of cloth is to be bleached, three hundred gallons of theſe leys may be made at once; in which caſe the ſame method of making them is to be obſerved that is above directed, only where ounces are mentioned, pounds are to be ſubſtituted in their place; that is to ſay, five pounds of lime, and twenty-two pounds of kelp muſt be taken for making three hundred gallons of kelp ley; and for the ſame quantity of the other ley, eight pounds of pearl-aſhes, and five pounds of lime, are the quantities that are requiſite.

The ley of pearl aſhes may alſo be prepared by diſſolving eight pounds of theſe aſhes in three hundred gallons of clear lime-water newly made. But for thoſe who chuſe to have a ſtronger or a weaker ley, by making leſs or more than three hundred gallons out of eight pounds of pearl-aſhes and five pounds of lime, the firſt method is

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* Dr. Black found that a ley free from air, when expoſed in an open veſſel, imbibed a ſmall quantity of air in twenty-four hours, and made a ſlight effervеſcence with acids. After a fortnight's expoſure in the ſame manner, it became entirely mild, effervеſced as violently with acids, and had the ſame effect upon lime-water as a ſolution of an ordinary alkali. Edinb. Eſſays and Obſervations, page 202.

is the beſt: becauſe by digeſting the ſalts and lime ſo long together, the fixed air will be more effectually expelled from the ſalts, and the lime more completely precipitated to the bottom.

If the aſhes that are to be uſed, be proved by the method pointed out in the ſeventeenth experiment, in order to know the proportion of ſalts that they contain; the ſtock leys may always be prepared of an equal degree of ſtrength, or they may be proved, when made, by a * balance, or a hydroſtatical ball.

When the cloth was boiled in this ley, it was at firſt diluted with an equal quantity of water: but in proportion as the linen advanced in whiteneſs, it was gradually more and more diluted: and after every boiling, the ley was entirely waſhed out before the cloth was ſpread upon the green.

The vitriolic acid was the kind that was uſed for ſouring; in the application of which, Dr. Home's rule of diluting a half or three quarters of an ounce of the acid with a gallon of water, may anſwer the purpoſe of a general direction: but as the oil of vitriol is not always of an equal degree of ſtrength, the beſt method of preparing theſe ſours, is to prove their ſpecific gravity by a * balance or hydroſtatical ball, and to fix upon that ſpecific gravity as the ſtandard, when they loſe

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* See the method explained in the table at the 17th experiment, in the note.

* See the concluſion of the note at the 17th experiment.

loſe their acidity by their action on the abſorbent earth of the cloth; for inſtance, if the liquor prepared for the firſt four raiſes the ball ſo far as that the degree marked 2 on the ſtem be at the ſurface, and if it loſes its ſourneſs by its action on the linen, let 2 be the future ſtandard of the firſt four. The ſame method is to be purſued in fixing the ſtandard of ſucceeding ſours; and here it is to be obſerved, that the ſeldomer linen is boiled before the firſt ſouring, or between any two applications of the ſour: and the weaker the ley is that is uſed in boiling, the ſmaller is the quantity of abſorbent earth that will be depoſited on the linen: conſequently the weaker may the ſour be that is applied to it.

The oil of vitriol, if properly dephlegmated, ought to be ſo heavy, as that the meaſure of a wine quart of it ſhould weigh three pounds and three quarters at leaſt: but I very ſeldom found any that weighed above three pounds and a half. In preparing the firſt ſour, I obſerved that ten noggins of the acid of this ſpecific gravity, were ſufficient to make two hundred gallons of ſour, of a proper degree of ſtrength, which quantity ſufficed to ſour eighty pieces of linen: and that it was not needful to take more than half as much of the acid, in preparing the ſame quantity of liquor for the ſecond or third ſour. After every application of the ſour, the linen was ſlightly boiled in ley before it was ſoaped for the boards.

As in other reſpects the cloth was managed in the uſual manner; it is not not needful to enter upon a detail of what is quite well known, it may ſuffice to obſerve that the linen was whitened in a ſhorter time than ordinary, and with ſcarcely half the quantity of aſhes which would have been requiſite, had not lime been uſed; that it did not require to be ſo frequently paſſed through the rolling boards, as if it had been boiled in the uſual ley: and that it has a firm, whole, and wirey thread, the want of which is one of the greateſt complaints againſt our linens. I will not have occaſion to enlarge in reſpect to to the colour or any other obvious property of the linen, as it has been laid before the Honourable Board, to whoſe determination the whole is ſubmitted.

At this time, when the common bleaching aſhes are conſiderably advanced in their price, though they are much inferior in their quality, and when the proſpect of a future ſupply is ſo very unpromiſing, that bleachers lie under great difficulties in carrying on their buſineſs: it is ſurely worthy of the Honourable Board to encourage the manufacture of aſhes. There certainly are materials in this country, of which a large quantity of aſhes might be made: but in America the fund of materials can ſcarcely be exhauſted; and the kind of aſhes moſt proper for bleaching, can eaſily be made. The eſtabliſhment of this manufacture would confer the greateſt advantages on both countries; the Americans would be well paid for clearing their lands of wood, and at the ſame time be enabled to make remittances for larger quantities of our manufactures than at preſent they are able to do:

while we could make returns for a great part of our aſhes by goods, whereas now the whole is paid in caſh. It is enough for me to give this hint: To the GUARDIANS of the Manufacture it is ſubmitted to take ſuch meaſures as to them in their ſuperior wiſdom it ſhall ſeem fit.

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AN

EXPLANATION

OF THE EFFECT OF

LIME

UPON

ALKALINE SALTS:

AND

A METHOD POINTED OUT WHERE-
BY IT MAY BE USED WITH SAFE-
TY AND ADVANTAGE

IN

BLEACHING.

By JOSEPH BLACK, M. D.

AN EXPLANATION OF THE EFFECT of LIME, &c.

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WHATEVER foundation there may be for diſtruſting and avoiding the uſe of lime in bleaching, as employed alone, this ſhould be no reaſon for entertaining any prejudice againſt a ley drawn from a proper mixture of lime and bleaching-aſhes, as it is now moſt certain and inconteſtible, that a ley of this kind does not contain the ſmalleſt particle of the lime.

Any perſon who is not acquainted with chemiſtry and chuſes to have ſome proof of this aſſertion, may have it by an eaſy experiment upon lime-water.

This fluid is now well known to conſiſt of a portion of the lime in ſubſtance intimately united and diſſolved into the form of a clear liquor, with about five or ſix hundred times its weight of water, which is the ſmalleſt proportion of water in which the lime will thus diſſolve. If we take a glaſs of this clear fluid, and drop into it a ſmall quantity of a clear ley drawn from pearl aſhes: the lime-water notwithſtanding the ſmall quantity of lime it contains will immediately be-

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In this experiment the particles of the lime are changed in ſuch a manner by thoſe of the ſalts, that they immediately loſe their diſpoſition to diſſolve, or to remain any longer diſſolved in the water.

And preciſely the ſame effect is produced when we take, inſtead of clear lime-water, a muddy mixture of lime and water, or a quantity of water with more lime in than it can diſſolve into a clear liquor; for provided only we add a ſufficient quantity of the alkaline ſalts, both the diſſolved lime, and that which was not diſſolved, will be ſo changed as to be rendered incapable of diſſolution.

When lime and aſhes are mixed together in due proportion, and a ley is drawn from this mixture, the ley is ſo far from having received any addition from the lime, that on the contrary the lime is found to have attracted and detained a conſiderable part of the ſalts of the ley, or more properly to have attracted and detained a ſubſtance which before was attached to the ſalts, and made up a conſiderable part of their bulk and weight. It is this ſubſtance, communicated by the ſalts, which inſtantly deprives the lime of its ſolubility, and gives it the form of a mild powder like chalk.

It is unneceſſary here to give a very particular account of this ſubſtance, or to explain how it produces this change upon the lime. Thoſe who would ſatisfy a curioſity with regard to this point, can do it only by making themſelves in ſome degree acquainted with chemiſtry.

But it is proper to obſerve at preſent, in order to underſtand what follows, that this ſubſtance is known in chemiſtry by the name of fixed or Mephitic air: that more or leſs of it is naturally and commonly attached to all the alkaline or bleaching ſalts; that while thus attached to them, it has the appearance and properties of a fixed and ſaline ſubſtance, and remains united to the particles in the ſalt, when this laſt is diſſolved in water. But that when ſeparated from the ſalt, and exhibited pure by itſelf, it always appears under the form of a ſubtile, light, tranſparent fluid, like air, only a little heavier than air.

This ſubſtance may be ſeparated from the ſalts, and exhibited in the above form by the means of an acid, ſuch as aqua-fortis, or the acid of vitriol: if either of theſe be dropped upon pearl-aſhes, for inſtance, or into a ley of pearl-aſhes, they produce a violent foaming ebullition, which is occaſioned by the ſudden ſeparation and expanſion of the Mephitic air, and this aereal matter will be clearly perceivable after its ſeparation, if the experiment be made in the following manner.

Provide a cylindrical glaſs-veſſel, about ſix inches diameter, and ten or twelve deep, ſuch as the confectioners have in their ſhops. Put into the bottom of it one pound of pearl-aſhes, and an Engliſh pint or two of water: after ſtirring theſe well together, pour in by ſmall quantities at a time, a mixture of equal parts of oil of vitriol and water, ſtirring gently now and then with a long and ſlender ſtick, until the dropping in ſome more of the acid liquor ſhall be found to occaſion no more ebullition; all this muſt be done in ſuch a manner as to produce no conſiderable diſturbance or agitation of the air about the top of the glaſs. When the experiment is thus performed, although the upper part of the glaſs which is not occupied by the mixture will ſeem to contain nothing but common air, the preſence of the Mephitic air will be made manifeſt, by gently letting down into it a bit of a burning candle faſtened to the end of a ſtick: as ſoon as the flame ſinks down a little below the mouth of the veſſel, it will be extinguiſhed as ſuddenly and perfectly as if it were dipped into water; and afterwards if a burning candle be ſet on the table, and the veſſel is raiſed a little above the candle, and then ſuddenly inclined towards it (as we would do if the veſſel were full of water, and it were intended to pour the water upon the candle,) the Mephitic air will run out, and extinguiſh the candle in the ſame manner.

This volatile and ſubtile matter, which before was detained by the pearl-aſhes in a fixed and condenſed ſtate, is thus ſet at liberty, becauſe the acid has a ſtronger diſpoſition to unite with the ſalt of the pearl-aſhes: the acid particles therefore unite themſelves ſuddenly, and with great force to the particles of the ſalts, and ſeparate and expel the Mephitic air.

Lime as was before obſerved, likewiſe ſeparates this ſubſtance from theſe ſalts, but in a different manner: the lime acts by a ſtrong attraction it has for the Mephitic air, in conſequence of which, it ſeizes and ſeparates this air from the ſalts, not allowing it to ſwell or break out into foam, but ſettling with it to the bottom in the form of a chalky powder, every atom of which has a part of the air firmly joined to it, and which will boil and foam violently when an acid is poured upon it. The ſalts continue diſſolved in the water, and are contained in the clear ley which flows over the lime, but having loſt their air will not now ſhew the ſmalleſt ebullition or foaming when mixed with an acid.

The ſalts upon being thus deprived by the lime of this aereal matter, are rendered incomparably more active, penetrating and powerful than they were before, and all the different kinds of aſhes or alkaline ſalts, can by this means acquire the ſame degree of activity. I alſo further affirm that this is the only method by which we can give them the greateſt degree of perfection they are capable of as bleaching materials: and, that when uſed in this ſtate, a much ſmaller quantity of them will anſwer the purpoſe, than when uſed in their ordinary condition.

In order to be ſatisfied of this, we muſt examine the different kinds of aſhes uſed in bleaching, and ſhall find that thoſe which are the moſt valued for this purpoſe, are only ſuch as contain a ſalt that is the moſt free from the abovementioned aereal matter.

Thus the pearl-aſhes, though containing by far the greateſt quantity of ſalt, and that very fine and free from ſulphur, and other groſſer impurities, are notwithſtanding found, when uſed by themſelves, to be very weak and almoſt entirely ineffectual in bleaching; much of the ſame kind with theſe is the ſalt of fern-aſhes, &c. Next to theſe, as containing a more powerful bleaching-ſalt, we may rank kelp; but the different kinds of Ruſſian-aſhes are much more highly valued, both as containing a conſiderable quantity of ſalt, and eſpecially on account of the nature of this ſalt, which is much more penetrating and powerful than any of the former.

Now if we would diſcover the reaſon of this difference among them, we ſhall find that thoſe ſalts which are the weaker and leſs effectual in bleaching, contain the greater quantity of fixed or Mephitic air, and will give out the greater quantity of it upon being mixed with an acid: They are beſt compared with one another in this reſpect by the following method.

Firſt, a ſtrong ley muſt be made of each of theſe aſhes, by infuſing ſuch of them in water as readily yield their ſalt, and boiling the reſt: and theſe leys muſt be kept in cloſe veſſels until uſed.

Secondly, the richneſs of theſe leys or the proportion of ſalt they contain, muſt be learned by evaporating a part of each.

Thirdly, take ſuch a quantity of each ley ſeparately as contains half an ounce of ſalt: put it into a florentine flaſk, ſet the flaſk upon one of the ſcales of a good and properly ſuſpended balance, and along with the flaſk in the ſame ſcale, ſet a little phial, containing an ounce or two of a mixture of equal parts of vitriolic acid and water. When things are in this ſituation, put a quantity of ſand or any other matter into the oppoſite ſcale until an exact equilibrium be obtained, and then taking off the flaſk and the phial, pour in the acid into the flaſk by ſmall quantities at a time, ſhaking the flaſk after every addition, until there be no more ebullition upon adding more of the acid: and now replacing the flaſk and phial in the ſame ſcale, obſerve how many grains weight muſt be put into that ſcale to reſtore the equilibrium which has been attracted by the expulſion and diſſipation of the Mephitic air; it is obvious that the number of theſe grains will be in proportion to the quantity of air which was attached to the ſalt.

When the experiment is made with this degree of exactneſs, the ſalts of the ſame denomination do not always yield preciſely the ſame quantity of air: this proceeds from accidental variations in the manufacture of them, or from their having been kept and expoſed to the air for a longer or ſhorter time; for there is always a ſmall proportion of Mephitic air mixed with the common air which we breathe: the aſhes therefore when long kept and expoſed, attract ſome of this by degrees, along with the moiſture which the air likewiſe contains, and thus have their weight increaſed, but are ſo much the worſe for it. And it is in the ſame manner that lime itſelf, eſpecially when expoſed dry, loſes its activity by degrees, and aſſumes the nature of a chalky powder.

The bleaching aſhes therefore vary more or leſs on account of accidental cauſes like theſe, but when they are freſh, there is always a plain and wide difference between the different kinds of them in reſpect of the air they contain. I have examined five kinds in this way, viz. the beſt Hungarian pearl-aſhes, caſhub, markoff, Muſcovy-weed-aſhes, and common kelp. I endeavoured to procure them as freſh as poſſible.

The pearl-aſhes yielded ſixty-ſix grains of air from half an ounce of the ſalt, which is at the rate of no leſs than 27½ pounds in the hundred; every hundred pound of the pure ſalt therefore, conſidered as diſtinct from the air, has no leſs than 37 pounds of air attached to it.

The ſalt of Caſhub-aſhes gave about twenty-five grains from the half ounce, which is at the rate of ten pound ſeven ounces nearly in the hundred pound, and every 'hundred pounds of the ſalt, conſidered as diſtinct from the air, has eleven pounds ten ounces of air joined to it.

The ſalt of markoff gave nineteen grains and ſomething leſs than a half, which is at the rate of about eight pounds only in the hundred, and every hundred pound of the ſalt, conſidered as diſtinct from the air, has only eight pound eleven ounces of air joined to it.

With reſpect to the ſalt of the Muſcovy-weed-aſhes, I was not a little ſurprized to find that it was totally free of air.

The ſalts which the leys of the two laſt afforded by evaporation, and eſpecially thoſe of the weed-aſhes, were in every reſpect perſonally ſimilar to the alkaline ſalts when ſharpened to the utmoſt by quick-lime, and particularly they melted into a fluid like melted wax, with a heat very little greater than that of boiling water: and upon being allowed to cool a little, attracted the moiſture of the air with exceſſive avidity; the earthy matter which remained after extracting the leys from theſe aſhes, had very much the appearance of lime, and I believe every chemiſt will agree with me in being perſuaded that it muſt be lime, as there is no practicable method of ſeparating the air ſo perfectly from the alkaline ſalts without having recourſe to it.

In the trial of common kelp, I found the ley of it abounded ſo much with common ſalt, that I could not make any certain eſtimate of the alkaline ſalts it contained. However I ſeparated the greateſt part of the common ſalt with the loſs of a great deal of the alkaline, and found that what remained, though it was loaded with ſulphur, contained but a moderate portion of air, and came near in this reſpect to the ſalt of the caſhub and markoff aſhes.

This difference among thoſe ſalts with regard to the quantity of aereal matter they contain, proceeds from the methods of manufacturing them, which are ſo many more or leſs ſucceſsful attempts to free them of it, and to reduce them to ſuch a form that they may be more eaſily kept for ſome time, without being liable to a change of their qualities: for it is to be attended to, that all the alkaline ſalts of vegetables, as firſt produced by merely burning the vegetable matter to white aſhes, contain a very large quantity of this fixed air; why the ſalts of ſome Ruſſian aſhes ſhould be ſo free from it need not appear extraordinary, ſince it is very probable that they are made up with lime, and we are certain that ſome of them even contain an over-proportion of it. There are, no doubt, ſome kinds of aſhes moſtly manufactured elſewhere, the preparation of which is more ſimilar to that of kelp; but I could likewiſe ſhew that the nature and effect of this preparation is ſuch, as to deprive them of more or leſs of their air; from whence it appears that in this caſe alſo the increaſe of activity depends upon the ſame circumſtance.

Thus therefore, as it is well known to every perſon acquainted with chemiſtry, that the alkaline ſalts are rendered incomparably more active, penetrating and powerful, by being deprived of their fixed air, ſo it likewiſe appears upon the whole, ſufficiently plain and certain, that their activity and power in bleaching depends upon the ſame circumſtance, and that they have more effect, every thing elſe being equal, in proportion as they contain leſs of this air. We have the beſt illuſtration and proof of this by reflecting upon the different nature of the beſt pearl-aſhes and of common kelp. The firſt is a pure alkaline or bleaching ſalt, totally free from ſulphur, and highly refined from all groſſer impurities; but it has a conſiderable quantity of air adhering to it, and is accordingly found when employed alone, to be a great deal too mild, and almoſt entirely ineffectual in bleaching. Kelp, on the contrary, proves very active and powerful, although poſſeſſed of no one good quality, ſetting aſide its cheapneſs, but that of containing a ſalt that is ſharp and penetrating from the want of air: for the kelp contains but a moderate quantity of this ſalt, and that loaded with ſulphur, and mixed beſides with a large quantity of common ſalt, both of which will, I believe, be reckoned at the beſt but uſeleſs ingredients.

May we not therefore very ſafely and fairly conclude, that if we free the bleaching ſalts entirely of this air, they will be ſo much the more active and powerful, and that a ſmaller quantity of them will ſerve the purpoſe, than when uſed in their preſent ſtate; there ſeems no reaſon to doubt of this, and ſeveral advantages will thus be gained beſides the ſaving of aſhes. The ſulphur which ſeveral of theſe aſhes contain, and the common ſalt with which the kelp ſo much abounds, if they be prejudicial to the cloth, will be applied to it in ſmaller quantities: a ſmaller quantity of earth will be depoſited in it, and if the uſe of ſours is to take out this earth, theſe may be uſed weaker and therefore cheaper than they are at preſent. It, no doubt, appears that ſome of the Ruſſian aſhes are capable of very little improvement in this way, as containing a ſalt from which the whole, or very near the whole of the air has been ſeparated already; but the great value which bleachers ſet upon aſhes of this kind, and the high price which they have thought it their intereſt to give for them, ſhew how important a quality this is, and plainly points out what muſt be done to give the aſhes which can be had cheaper, the ſame degree of perfection.

If we would therefore entirely ſeparate the air from the bleaching ſalts we muſt have recourſe to lime; there is no method hitherto known of ſucceeding without it, and we can hardly wiſh for a cheaper or eaſier method. The only point that remains to be ſettled, is the quantity that may be ſafely uſed; in entering upon this, it is neceſſary to obſerve, that lime and Mephitic air are capable of uniting together in one certain proportion only.

A given quantity of lime can receive only a certain quantity of air, and we cannot make it receive any leſs: if a ſmaller quantity is offered to it, or mixed with it than what is neceſſary to ſaturate the whole of it, this ſmaller quantity will be attracted by a correſponding part of the lime only, and will convert it into a mild chalky powder, the reſt of the lime will remain in the ſame ſtate as before. It may therefore ſeem improper to uſe more lime than what is juſt neceſſary for attracting the air of the ſalts, as the ſuperfluous lime which retains its activity, might be prejudicial: but there is no great reaſon to apprehend any harm from it; ſince it is not ſo much diſpoſed to diſſolve in a ley, however free of air, as it is to diſſolve in pure water, and will not diſſolve at all unleſs the ley be exceſſively dilute or poor of ſalts. If this however ſhould be the caſe, there is nothing more eaſy than to diſcover it at once, and apply an effectual remedy. If the ley is ſuſpected to contain any lime, we can put it to the moſt rigorous trial in a moment, by taking a glaſs of it and dropping into it a ſmall quantity of clear ley, or ſolution of pearl-aſhes: if it does not immediately become white and milky as lime-water would do, we may be perfectly certain there is no lime in it, for it is impoſſible in this caſe that there ſhould. And if on the other hand, a manifeſt and plain milkineſs appear, the lime may be eaſily ſeparated by ſprinkling equally over the whole ſurface of the ley, ſome dry pearl-aſhes finely pounded, and in the proportion of an ounce or an ounce and a half to every eight Engliſh gallons, according as the ley ſeems to contain more or leſs lime: or inſtead of this, fern-aſhes will anſwer the purpoſe equally well, if uſed in the ſame manner in the proportion of half a pound or more to every eight gallons. The effect of this practice is obvious, and if it ſhould not fully anſwer the purpoſe at firſt, which however is highly improbable, it is eaſy to repeat it.

Although we can thus with a little attention be perfectly ſecure from any harm the lime can do, it would at any rate be unfrugal to uſe too much of it; but at the ſame time it is plain that the preciſe quantity of lime which may be uſed with advantage with the different aſhes, cannot be exactly limited: it depends upon the goodneſs of the lime, and upon the nature of the aſhes, which as was before obſerved, are liable to ſome variation. Pot-aſhes which contain a ſalt that is much loaded with air, will require ſo much the more lime, and if they at the ſame time contain a large quantity of ſuch ſalt, they will ſtill require ſo much the more. The lime itſelf is likewiſe liable to great variation in ſtrength and efficacy: the beſt is that which is made of the fineſt, that is to ſay the pureſt lime-ſtone, which has been the moſt thoroughly burnt, and which after burning has not been much expoſed to the air; the manner of burning it, eſpecially, produces a conſiderable variety in its ſtrength. The lime-ſtone in its crude or natural ſtate is fully loaded or ſaturated with fixed air: the effect of burning it is to expel, by means of a ſtrong heat, this air which it ſtrongly retains, and which, when it has been expelled, the lime is diſpoſed to attract again with the greateſt force; but it is ſeldom burnt ſo thoroughly that the whole of its air is expelled, and it is only a quantity equal to what has been expelled which the lime is diſpoſed to attract and recover.

As the lime which is quarried and burnt in different places, is therefore extremely different in ſtrength, as the different kinds of aſhes will require very different proportions of the ſame lime, and even the aſhes of the ſame denomination will not be always exactly alike; we cannot determine and limit the quantity of lime that may be proper on every occaſion, we muſt have recourſe to the examination of the ley, and we can eaſily put it to as exact a trial to know whether it has had lime enough as that which was deſcribed above, to know whether there be any ſuperfluous and diſſolved lime in it. We need only to take a glaſs of pure and clear lime-water, and pour into it a ſmall quantity of the ley when freſh made and ſettled; if it makes the lime-water manifeſtly muddy and white, we may be certain there is ſome air in it, and that enough of lime has not been uſed to extract this air. If we chuſe to remedy this defect in the preſent ley, which is however hardly worth while: we may do it in ſome meaſure by ſifting equally over the whole ſurface of it ſome fine and dry ſlaked lime, an ounce or two to every two gallons, but the lime will not be ſo effectual in this caſe as the alkaline ſalt in the former, becauſe it will not diſſolve in the ley, not even for a moment, and cannot therefore be ſo intimately and equally applied to the particles of the ſalts ; a bleacher however, who generally uſes the ſame kind of lime and the ſame kind of aſhes, will ſoon learn by the help of theſe trials to hit the due proportion ſo nearly as to need no amendment.

I ſaid above that in making the laſt trial of the ley it ought to be taken when freſh made and ſettled, the reaſon of this is obvious, for although it be perfectly free of air when new made, if it be allowed to ſtand for ſome days, and often expoſed to the air, it will certainly attract a little Mephitic air from the atmoſphere : this therefore ſuggeſts a caution to have the copper or other veſſel in which the mother ley is kept, as well covered as poſſible. Upon the whole therefore, the method of uſing lime which I would propoſe it as follows.

In making the firſt or mother ley of common kelp, for example, I imagine that one half of the kelp that is commonly uſed will be ſufficient when it is ſharpened with lime, and a quantity of dry ſlaked lime may be mixed with it at firſt, in the proportion of about twenty pounds to every hundred of kelp : if this be found too much or too little, it is eaſy to correct it, and vary the proportion afterwards.

When the caſhub or markoff-aſhes are uſed, the quantity of them may be diminiſhed in the ſame proportion, and the ſame or a ſomewhat ſmaller proportion of lime may be added.

I believe Spaniſh kelp, or barilla-aſhes will bear one half of its weight of lime, and that one fourth of this kelp that is employed at preſent will anſwer the purpoſe.

Pearl-aſhes will probably require double or triple their weight of lime, and will become ſo much more active and powerful that they may be diminiſhed to one fifth or one ſixth of their uſual quantity.

And I am perſuaded that fern-aſhes employed with lime may anſwer the purpoſe of all others: and from what judgment I can hitherto form of them, I ſuppoſe they are nearly equal to common kelp in reſpect of the proportion of effective ſalts they contain, and that they will require the ſame or a ſomewhat greater proportion of lime.

N. B. The proper manner of mixing pearl or other ſimilar rich aſhes with lime, is to mix them at firſt by means of a ſmall quantity of water, viz. no more than what is ſufficient to allow an extremely ſmall quantity of the ley to gather clear at the top when the mixture is allowed to ſettle a while: and after examining this ley, by taking out a little of it with a tea-ſpoon, and finding it right, as much water may be poured in as is neceſſary: but the lime muſt be well ſtirred up before it is allowed to ſettle again.

AN

ABSTRACT

OF THE FOREGOING

ESSAYS,

CONTAINING

PRACTICAL RULES and DIRECTIONS

For the Preparation and Uſe of particular

SOURS and LEYS

IN

BLEACHING.

By DAVID MACBRIDE, M. D.

AN

ABSTRACT

OF THE FOREGOING

ESSAYS,

CONTAINING

Practical Rules and plain Directions for the Preparation and Uſe of the Sours made of Oil of Vitriol: and of the Leys made of Bleaching-aſhes with the Addition of Quick-lime.

THE dark colour of unbleached linen depends on an oil that is natural to the flax: and is intimately blended with the ſubſtance of the cloth.

When this oil is completely waſhed out, and diſcharged from the cloth, then the linen becomes perfectly white.

But this oily matter will not naturally mix with, nor diſſolve in water: hence it can never be completely waſhed out and diſcharged by the means of pure water alone.

Therefore bleachers are obliged to make uſe of leys prepared from aſhes, in order to render the oily matter capable of mixing with, and of being diſſolved in water, and conſequently capable of being completely waſhed out and diſcharged.

Every time the leys are uſed, they let fall an earthy matter on the cloth.

As this earthy matter will not naturally mix with, nor diſſolve in water, it cannot be completely waſhed out by water alone: therefore, it will at length be ſo increaſed, as to prevent the leys from uniting readily with the oily matter, and rendering it capable of being diſcharged.

Hence ariſes the neceſſity of uſing ſours as they are peculiarly fitted to diſſolve the earth, and make it capable of being waſhed out of the cloth.

The aſhes whence bleachers uſually prepare their leys, are common kelp, caſhub, two kinds of barilla, markoff, the Ruſſia-weed, and the pearl.

Of theſe the pearl-aſhes, the Ruſſia-weed, and the markoff are the moſt proper for the purpoſes of bleaching, as containing the greateſt proportion of that particular kind of ſalt, which has the peculiar property of rendering oily matters capable of mixing with water; for the caſhub, the barilla, and the kelp, are all of them found to contain a conſiderable ſhare either of brimſtone, or common ſea-ſalt, or of both together. Theſe things are injurious and foreign to the true intentions of bleaching: for the admixture of ſea-ſalt tends to weaken and deſtroy the texture of the cloth; and the brimſtone abates very remarkably the whitening power of the different kinds of aſhes, wherewith it chances to be combined. (See the 17th, 18th, and 19th experiments of Dr. Ferguſon's Eſſays.)

The pearl-aſhes are nevertheleſs found to be weak and ſlow in their operation, while the markoff and the Ruſſia-weed are obſerved to be exceedingly ſtrong and quick, in regard to their power of diſcharging the dark colour of the cloth.

This extraordinary power of the Ruſſian aſhes is proved to depend on their having a quantity of lime in them.

And it is demonſtrably proved, that the other kinds of aſhes may have their power vaſtly increaſed by the addition of lime, particularly the pearl-aſhes: one pound of which, when mixed up with lime, will do as much ſervice as two pounds without this addition.

And yet, notwithſtanding the lime is thus added to the aſhes in order to prepare the ley: this ley when properly prepared, does not contain an atom of lime. (See Dr. Black's 1ſt and 2d experiments.)

So that it plainly appears there can no injury ever happen to the linen from any ſuppoſed fiery quality in the lime.

And conſequently that the uſe of lime in bleaching is perfectly ſafe and innocent.

Of all the different ſours made uſe of by Bleachers, thoſe prepared by diluting the oil of vitriol in a proper quantity of water, are by far the moſt effectual, and the ſafeſt in their operation; for the butter-milk, and the infuſions of wheat and of bran, which are ſometimes applied to this purpoſe, can never be brought to any fixed point of ſtrength, in regard to acidity or ſourneſs, as being liable to much variation from changes in the weather, and from the different lengths of time that they may chance to be kept. And thoſe kinds of ſours are moreover exceedingly apt to run into a putrid ſtate, and then they muſt infallibly rot the cloth. The vitriolic ſour on the contrary, is never liable to the leaſt variation in regard to ſtrength, either from length of time, or change of weather: and is ſo far from ever having a tendency to putrefaction, that it will preſerve any kind of vegetable ſubſtance, or even fleſh from rotting.

Since the freeing of linen from the earthy matter that is let down on it from the leys, is the principal end that bleachers ſhould have in view when they make uſe of ſours, the application of them certainly ought not to be deferred, according to the common practice, until the cloth is nearly white. An earlier application of them would undoubtedly ſhorten the time of bleaching; for the cloth being earlier freed from the earthy matter, would be much better prepared for the future uſe of the leys, which would now more readily lay hold of, and unite with the oily matter, and render it much ſooner capable of being waſhed out and diſcharged, than when the force of the ley is blunted in ſome meaſure by a load of earthy matter. Yet though the earthy matter be entirely diſcharged by the firſt ſouring: after ſome applications of the leys, it is again neceſſary to repeat the uſe of the ſour, in order to free the cloth from the earth again let down upon it by the leys.

The ſtrength of the ſour ought to be ſo adjuſted, as that it may be ſpent upon the earthy matter: for if the ſourneſs of the liquor in which the cloth is ſteeped, be not taken away or deſtroyed by the melting of the earthy matter that ought to be diſſolved by it; when there is none of the earth at all left in the linen for the acid to work on, then the ſour acts immediately upon the ſubſtance of the thread itſelf, and greatly injures the texture of the cloth.

The oil of vitriol, which is commonly expoſed to ſale, is not always of one ſettled and determined degree of ſtrength, therefore the bleacher ought to be furniſhed with ſome certain rule, whereby he may regulate the proportion of water which is to be added to the vitriol, in order to dilute it ſufficiently and render it perfectly ſafe in the application.

A contrivance in the nature of the inſtrument (called an Hydrometer, or more properly Areometer, or Hydroſtatick ball) which is commonly uſed to determine the ſtrength of ſpirituous liquors, might be made to anſwer the ſame purpoſes with the greateſt exactneſs, in regard to the ſours prepared from the oil of vitriol; for inſtance, if the liquor prepared for the firſt ſour, raiſes the ball ſo as that the number 2 on the ſtem reſts at the ſurface, and if the ſourneſs of the liquor be deſtroyed by the melting of the earthy matter that ought to be diſſolved by it, let 2 be the future ſtandard of the firſt ſours; and ſo with reſpect to thoſe that follow.

And therefore the Truſtees ſhould offer a præmium to the perſon who ſhall contrive and execute the moſt accurate and ſimple inſtrument of this nature.

However, until ſuch an inſtrument ſhall be contrived, the bleacher may put 200 gallons of pure water to ten noggins of the oil of vitriol, which is uſually ſold: and this will ſuffice for 80 pieces of cloth.

This however is to be underſtood as deſigned for the firſt ſouring: for in the ſubſequent ones, the vitriol muſt be more and more diluted, and the ſours every time made gradually weaker; becauſe the quantity of earthy matter which the ſour is intended to diſſolve, and render capable of being waſhed out of the cloth, is gradually diminiſhed at every ſouring; for it is to be obſerved, that the ſeldomer the cloth is boiled before the firſt ſouring, or between any two applications of the ſour; and the weaker the ley is that is uſed, the ſmaller quantity of earthy matter will be let down upon the cloth, conſequently the weaker may the ſour be that is applied to it.

Cloths which are juſt taken out of the ſour, ſhould not be put immediately into the rubbing boards: becauſe if any thing ſour remains in the linen, it will not take the ſoap, and ſo of courſe be in danger of being rubbed to pieces; for which reaſon, the cloth after being taken out of the ſour, ſhould not only be well waſhed, but ſhould moreover be ſlightly ſcalded in the ley before it is expoſed to the action of the boards, and then it will take the ſoap freely.——So far with regard to the ſouring of linen.

As to the management of the leys, it has been already obſerved that the leys prepared from all the different kinds of aſhes, except the Ruſſia-weed (in which there is already too great a proportion of lime) may be rendered much more active by the addition of lime; for this enables the ley to unite itſelf completely and ſpeedily with the oily matter of the cloth, and therewith to form a ſoapy mixture that immediately diſſolves in water. It is for this reaſon, that in making common ſoap, there is a neceſſity for adding lime to the ley of the potaſh, or kelp, which otherwiſe would never thoroughly incorporate with the oil or the tallow. Upon the ſame principle then it is demonſtrated in the foregoing eſſays, that if the leys uſed in bleaching, were always rendered thus active by the addition of lime, the oily matter of the linen would be much ſooner taken out, and at half the expence of materials.

This is particularly applicable to the ley made from the pearl-aſhes, which when thus quickened by the lime, are the moſt powerful whiteners of any. The caſhub, the barilla, and the kelp, being combined with brimſtone or ſea-ſalt, which are injurious to them, with regard to the purpoſes of the bleacher, are never to be uſed when the pearl-aſhes are to be had. However even theſe foreign and injurious ingredients will be rendered leſs hurtful by the addition of lime. So that in general, this may be ſaid to add greatly to the power and activity of leys of any kind.

Theſe active leys may be made in two ways, both of them exceedingly eaſy. Firſt, by mixing the lime and the aſhes together, with a ſmall quantity of water, and then throwing them into the keeve to be further diluted and diſſolved.—The aſhes muſt be firſt reduced to powder, and the lime ſhould always be taken freſh from the kiln, and thoroughly burnt. Theſe mixed together with a little water and well ſtirred, and then thrown into three hundred gallons of water, in the following proportions of the different aſhes to five pounds of lime, will give three hundred gallons of active ley, viz.

Common kelp, - - -	22 pounds.
Caſhub, - - - - -	the ſame.
Sweet barilla, - - -	14 pounds.
Pearl-aſhes, from	8 to 9 pounds.

When the groſs and inſoluble parts have all ſubſided, and the ley becomes quite clear, it is then fit for uſe, and may be drawn off occaſionally into other veſſels from the one wherein it was firſt made.

The other method of making the active ley, is to add the aſhes to lime-water ready made.

Lime-water may be made in large quantities, and preſerved for uſe as long as people may deſire it ; for it never ſpoils by keeping, provided it be kept in veſſels extremely well covered.

There is no occaſion for much nicety with regard to the proportions in making lime-water : all that is requiſite is to take care that the lime be thoroughly burnt, and freſh from the kiln. A dozen of pounds, or leſs of ſuch lime will make three or four hundred gallons of lime-water. The water is to be poured on the lime, and the whole well ſtirred for eight or ten minutes, and then allowed to ſettle: and when it falls perfectly fine it will be fit for uſe.

The lime-water being thus prepared, let the different kinds of aſhes be diſſolved in common water, and then added to the lime-water in the following proportions, viz.

Pearl-aſhes, - - - 3 pounds at moſt, but in general 2 pounds 8 ounces will be ſufficient.

Barilla - - - - - - 4½ pounds.

Kelp or caſhub - - 7¼ pounds.

Let each of theſe proportions be firſt of all diſſolved in two gallons of water (the pearl-aſhes diſſolve in cold water, the reſt require it to be boiling:) and when the groſs part has ſubſided, pour the clear into ninety-eight gallons of lime-water, and let the whole be thoroughly ſtirred; and thus there will be made a hundred gallons of active ley.

On the firſt mixture of the ſolution of the aſhes with the lime-water, the whole will become as white as milk: but in a few hours the lime will, all of it, fall to the bottom in a fine white powder, preciſely like powdered chalk.

Theſe active leys (whether made in the way juſt now mentioned, or by mixing the lime and the aſhes together from the firſt) are to be mixed with an equal quantity of water when they are uſed for cloth that is brown: but in proportion as the cloth advances in whiteneſs, they muſt be weakened gradually more and more. Beſides, they are not to be made in larger quantities than what may be wanted for immediate uſe: becauſe they loſe their power on being expoſed to the open air, and in time will become as weak as if no lime had been uſed in preparing them; for this reaſon the leys ought to be kept in covered veſſels: Porter-butts or hogſheads, ſet on an end with cloſe covers, and the holes for drawing off the liquor, made about 8 inches from the bottom, would ſeem to be the moſt convenient kind of veſſels for containing either the active leys or the lime-water.

As the natural ſtrength of the different kinds of aſhes can never be expected to be always preciſely the ſame, ſo the proportions of lime which have been directed, may not always happen to be perfectly accurate.

But there is an eaſy way of knowing whether the ley be made ſufficiently active, and whether lime enough has been added in preparing it. Take up a little of the ley, after it has fallen quite fine, and put it into a glaſs: then drop into it a little ſtrong vinegar, or ſome of the oil of vitriol, diluted with half its weight of water.

If the ley boils up, and bubbles ariſe in the mixture while the acid is dropping into it, it may then be concluded that the ley is not ſufficiently quickened, and that it ſtill requires a little more lime: but if on the contrary, no bubbles ariſe, then it may be held as certain that there has been lime enough given. Or another way of proving the ley is to drop a little of it into a glaſs of perfectly clear lime-water, if the mixture grows white, it then ſhews that the ley has not had lime enough, and therefore a little more muſt be added; but if the mixture preſerves its tranſparency, then the ley is ſufficiently active.

On the other hand, if it be deſired to know whether there has not been too much lime added: take up a glaſs of the ley, and drop into it a little of the tranſparent ſolution of pure pearl-aſhes, and obſerve whether the mixture grows white and milky: if it does, and lets fall a white ſediment to the bottom of the glaſs, it then ſhews that there is too much lime in the ley, and that it requires the addition of a little more aſhes. But if the mixture remains clear, then the ley is right as to the proportion of both lime and ſalts: eſpecially if it alſo preſerves its tranſparency on the addition of a little clear lime-water.

Theſe active leys, as well as thoſe commonly uſed, will be more ſpeedy in their effects if poured hot upon the linen, or if the cloth be boiled in them.

The cloth muſt never be ſpread on the Green with the ley in it, but ought always to be previouſly well waſhed before it is laid out.

It ſeems to be a bad practice in bleaching to make uſe of the ſame ley for three or four times, with the addition of a ſmall quantity of freſh, to what is called the burnt ley; becauſe the leys that are often uſed, have their whitening power entirely deſtroyed by the oily matter which they take up from the cloth: and conſequently when applied again, thus loaded with oil, they not only become uſeleſs, but hurtful in regard to the diſcharging of the dark colour, and ſo muſt rather tend to protract than ſhorten the proceſs of bleaching.

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On the other hand, if it be asked to [illegible] whether there has not been [illegible] the use of lime, and [illegible] little of the argument for [illegible] and objects, whether the [illegible] diminished? [illegible] the bottom of the [illegible] of the [illegible] clear, then [illegible] is right as to the [illegible] of both lime and [illegible]: especially [illegible] its impla-rency on the addition [illegible] clear lime-water.

[illegible] as well as [illegible] poured hot upon the linen, or if the cloth be boiled in them.

The cloth must never be ſpread on the Green with the lime in it, but [illegible] ſhould be previouſly well waſhed before it is [illegible].

It ſeems to [illegible] to [illegible] with the addition of a ſmall quantity of [illegible] what is called the burnt lees; becauſe the leys that are often uſed, have their whitening power entirely deſtroyed by the oily matter which they take up from the cloth, and [illegible] when applied warm, thus loaded with oil, they not only become uſeleſs, but hurtful in regard to the diſcharging of the dark colour, and to muſt rather tend to protract than ſhorten the proceſs of bleaching.

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